SPECIFICATION NUMBER 113

MARCH 1, 1962

X376 PITCH FAN SPECIFICATION

VZ-11

LIFT FAN FLIGHT RESEARCH AIRCRAFT PROGRAM

CONTRACT NUMBER DA44-177-TC-715

GENERAL ELECTRIC

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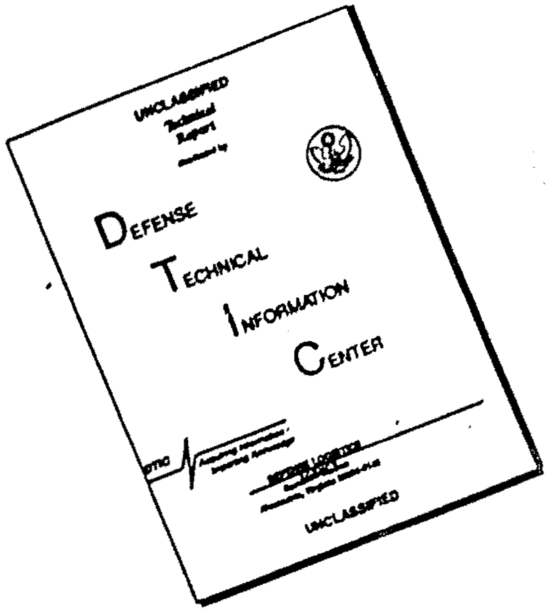

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LIFT FAN FLIGHT RESEARCH AIRCRAFT PROGRAM

CONTRACT DA44-177-TC-715

X376

PITCH FAN SPECIFICATION

Specification No. 113

March 1962

APPROVAL STATUS:

GENERAL ELECTRIC COMPANY
FLIGHT PROPULSION LABORATORY DEPARTMENT
CINCINNATI, OHIO

Spec. No. 113

Date March 1, 1962

MODEL SPECIFICATION

PITCH FAN

GENERAL ELECTRIC COMPANY

X376

1. SCOPE

1.1 Scope: This specification covers the characteristics of the X376 Pitch Fan intended for use in a piloted flight research airplane.

1.2 Classification. The General Electric X376 Pitch Fan is a high lift-weight ratio gas-driven lift fan for supplying augmented control and trim force in V/STOL systems. The X376 Pitch Fan comprises a single stage, tip-turbine driven lift fan supplied with turbojet exhaust gas bleed through two separate nozzle scrolls. The double scroll arrangement provides single-engine operating capability in a two-engine, cross-ducted lift propulsion system.

1.3 Basic Gas Generator: Performance contained herein is based on gas as supplied by the X353-5B system operating at rated conditions with zero louver vector and stagger angles as described in X353-5B Propulsion System Specification, Spec. 112. Official performance test results will be corrected to this standard gas source (Reference paragraph 3.4)

2. APPLICABLE DOCUMENTS

2.1 The following specifications, standards, drawings and publications with issue date prior to June 1961 shall be used as a guide in the design of the pitch fan.

SPECIFICATIONS

Military: MIL-E-5007B Engines, Aircraft, Turbojet, General Specification for,

General Electric: Specification No. 112, Model Specification, Convertible V/STOL Lift Fan Aircraft Engine, General Electric Company, X353-5B, January 15, 1962.

PUBLICATIONS

Air Force - Navy Aeronautical Bulletin 343n, 14 December 1960 entitled "Specifications and Standards Applicable to Aircraft Engines and Propellers, Use of."

3. REQUIREMENTS

3.3 Mock-Up. A full scale mock-up of an X376 Pitch Fan shall be prepared for installation in an airplane mock-up.

3.4 Performance Characteristics. The ratings and curves shown are based on the terms and standard conditions defined in MIL-E-5008B. These data indicate uninstalled performance of the pitch fan under standard conditions with pitch fan scroll nozzle area adjusted to produce bleed gas flow quantities as described in paragraph 3.4.4 divided between the two scroll inlets with a pitch fan gas duct entrance loss coefficient ($\bar{\omega}_{15.1}$) of 0.15 and a ducting total pressure loss coefficient ($\bar{\omega}_{15.2}$) of 1.30 in each duct * These data include fan inlet losses (without closure) commensurate with an inlet configuration as defined on reference drawing 4012028-545 and fan exit losses commensurate with an exit configuration corresponding to the maximum thrust position of the thrust reverser defined in reference drawing 4012028-545. These data do not include any external effects such as reingestion or ground effect.

3.4.1 Fuel: Not applicable

3.4.1.1 Alternate Fuel: Not applicable

3.4.1.2 Emergency Fuel: Not applicable

3.4.1.3 Fuel Contamination: Not applicable

3.4.3 Oil Consumption: Not applicable

3.4.4 Ratings: The performance ratings shall be as listed in Table I.

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* $\bar{\omega}_{15.1}$ is based on q at diverter valve discharge, station 5.2

$\bar{\omega}_{15.2}$ is based on q in the duct following the entrance loss, station 15.2

TABLE I

X376 PERFORMANCE RATINGS AT STANDARD SEA LEVEL STATIC CONDITIONS

DESIGN SETTING

Ratings (X353-5B Turbojet Power Setting)	Gross Thrus pounds (min)	Fan Rotor rpm (max)	Gas Flow lbs/sec (max)	Reference Gas Temp. ^{o}F
Military	1628	3931 **	9.29 ***	1236
*Military - Single Engine	895	2897	4.65	1236
95%	1268	3450	8.51	1082
90%	754	2640	6.95	899

* "Military, Single Engine" denotes condition with one scroll-half supplied with exhaust gas from turbojet engine. This corresponds to one-engine-out in a two-engine cross-ducted installation.

** 100% Fan speed is 4074 rpm. Corresponding lift at 100% fan speed would be 1747 lbs and corresponding bleed flow would be 10.32 lbs/sec.

*** Scroll nozzle area is the same for Tables I and II. For Table I this results in a gas flow of 9.29 lbs/sec corresponding to 10.6 percent of the diverter valve discharge gas flow from each of two X353-5B propulsion systems when operating at military rated conditions as given in Specification 112.

3.4.5 Estimates: Estimated performance and curves, shown in Tables II,III and IV and in Figures 1 through 8 inclusive, constitute part of this specification.

3.4.5.1.2 Performance Correction Curves: Data for correcting performance outlined in paragraph 3.4.5 are presented in Table V and Figures 9 through 13 inclusive.

TABLE II

X376 ESTIMATED PERFORMANCE AT 2500 FT. ALTITUDE ANA 421 STANDARD HOT DAY

DESIGN SETTING

Ratings (X353-5B Turbojet Power Setting)	Lift Thrust Pounds (min)	Fan Rotor rpm (max)	Gas Flow Lbs/sec (max)	Reference Gas Temp. ^{o}F
Military	1300 1329	3773	7.87 **	1250
*Military - Single Engine	712	2783	3.93	1250
95%	864 890	3051	6.77	1055
90%	563 580	2453	5.65	945

* "Military, Single Engine" denotes condition with one scroll-half supplied with exhaust gas from turbojet engine. This corresponds to one-engine-out in a two-engine, cross ducted installation.

** Scroll nozzle area is the same for Table I and II. For Table II this results in a gas flow of 7.87 lbs/sec corresponding to 10.6 percent of the diverter valve discharge gas flow from each of two X353-5B propulsion systems when operating at military rated conditions as given in Specification 112.

TABLE III

X376 ESTIMATED PERFORMANCE AT STANDARD SEA LEVEL STATIC CONDITIONS

HIGH LIFT SETTING

Ratings (X353-5B Turbojet Power Setting)	Lift Thrust Pounds (min)	Fan Rotor rpm (max)	Gas Flow Lbs/sec (max)	Reference Gas Temp. ^{o}F
Military	1885	4234	11.61 **	1236
*Military - Single Engine	1047	3134	5.80	1236
95%	1458	3698	10.59	1082
90%	855	2807	8.53	899

* "Military, Single Engine" denotes condition with one scroll-half supplied with exhaust gas from turbojet engine. This corresponds to one-engine-out in a two-engine, cross-ducted installation.

** Scroll nozzle area is the same for Tables III and IV. For Table III this results in a gas flow of 11.61 lbs/sec corresponding to 13.3 percent of the diverter valve discharge gas flow from each of two X353-5B propulsion systems when operating at military rated conditions as given in Specification 112.

TABLE IV

X376 ESTIMATED PERFORMANCE AT 2500 FT. ALTITUDE ANA 421 STANDARD HOT DAY

HIGH LIFT SETTING

Ratings (X353-5B Turbojet Power Setting)	Lift Thrust Pounds (min)	Fan Rotor rpm (max)	Gas Flow Lbs/sec (max)	Reference Gas Temp. $^{\circ}F$
Military	1502	4053	9.82 **	1250
*Military - Single Engine	837	3014	4.90	1250
95%	984	3252	8.34	1055
90%	634	2598	6.90	945

* "Military, Single Engine" denotes condition with one scroll-half supplied with exhaust gas from turbojet engine. This corresponds to one-engine-out in a two-engine, cross-ducted installation.

** Scroll nozzle area is the same for Tables III and IV. For Table IV this results in a gas flow of 9.82 lbs/sec corresponding to 13.2 percent of the diverter valve discharge gas flow from each of two X353-5B propulsion systems when operating at military rated conditions as given in Specification 112.

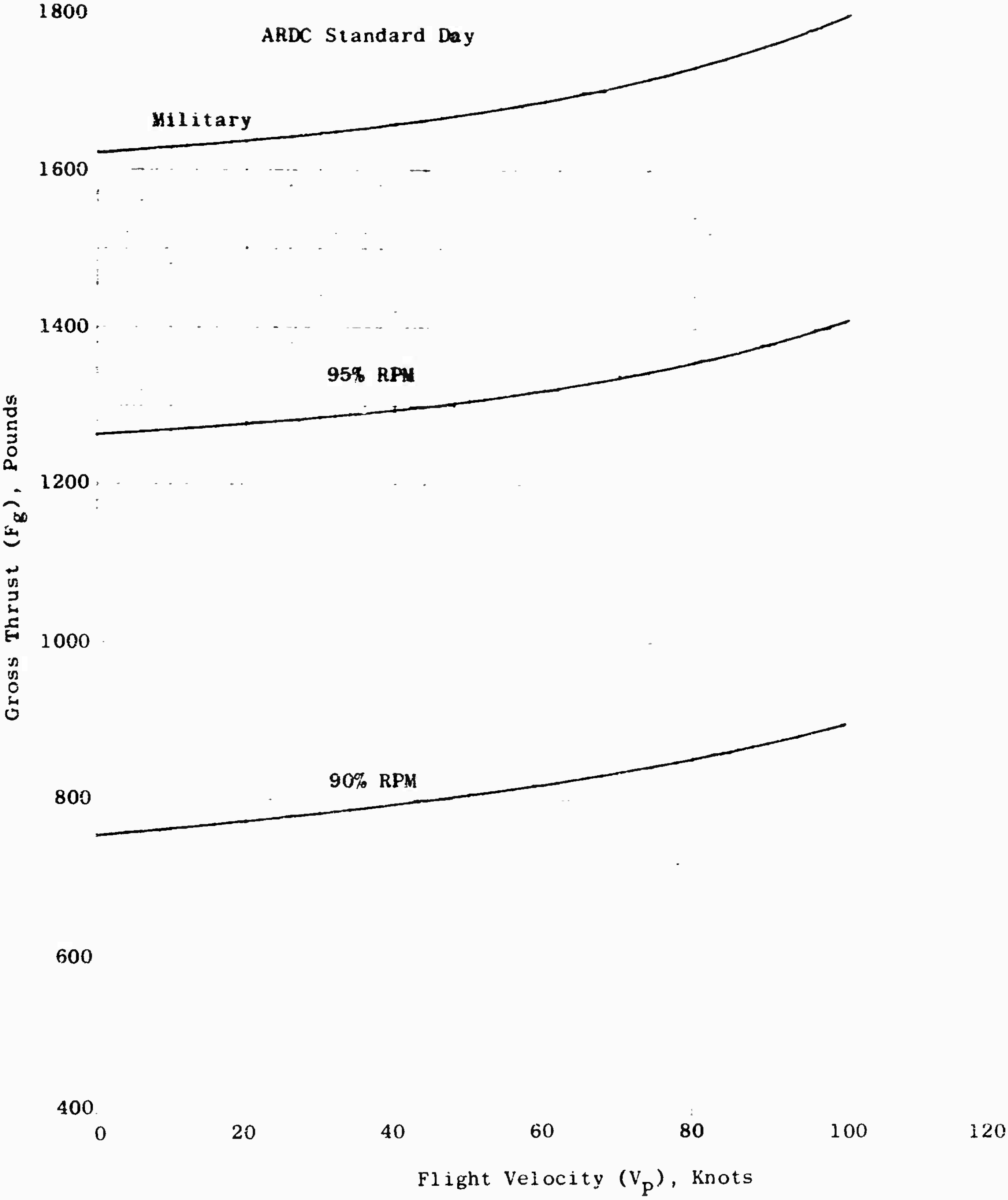


Figure 1. Gross Thrust Vs. Flight Velocity Design Lift Setting - Sea Level

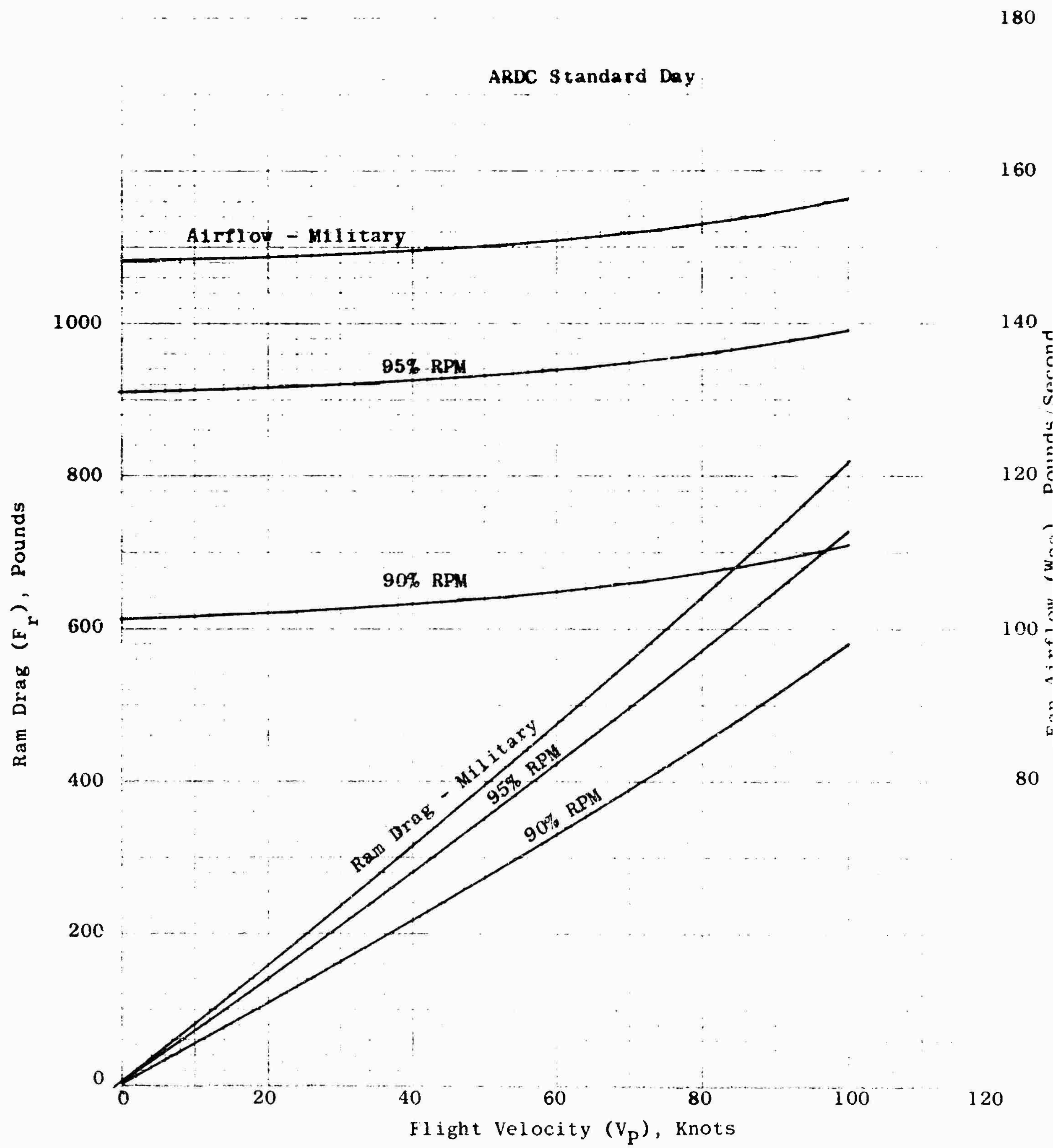


Figure 1a. Ram Drag And Airflow Vs. Flight Velocity Design Lift Setting Sea Level

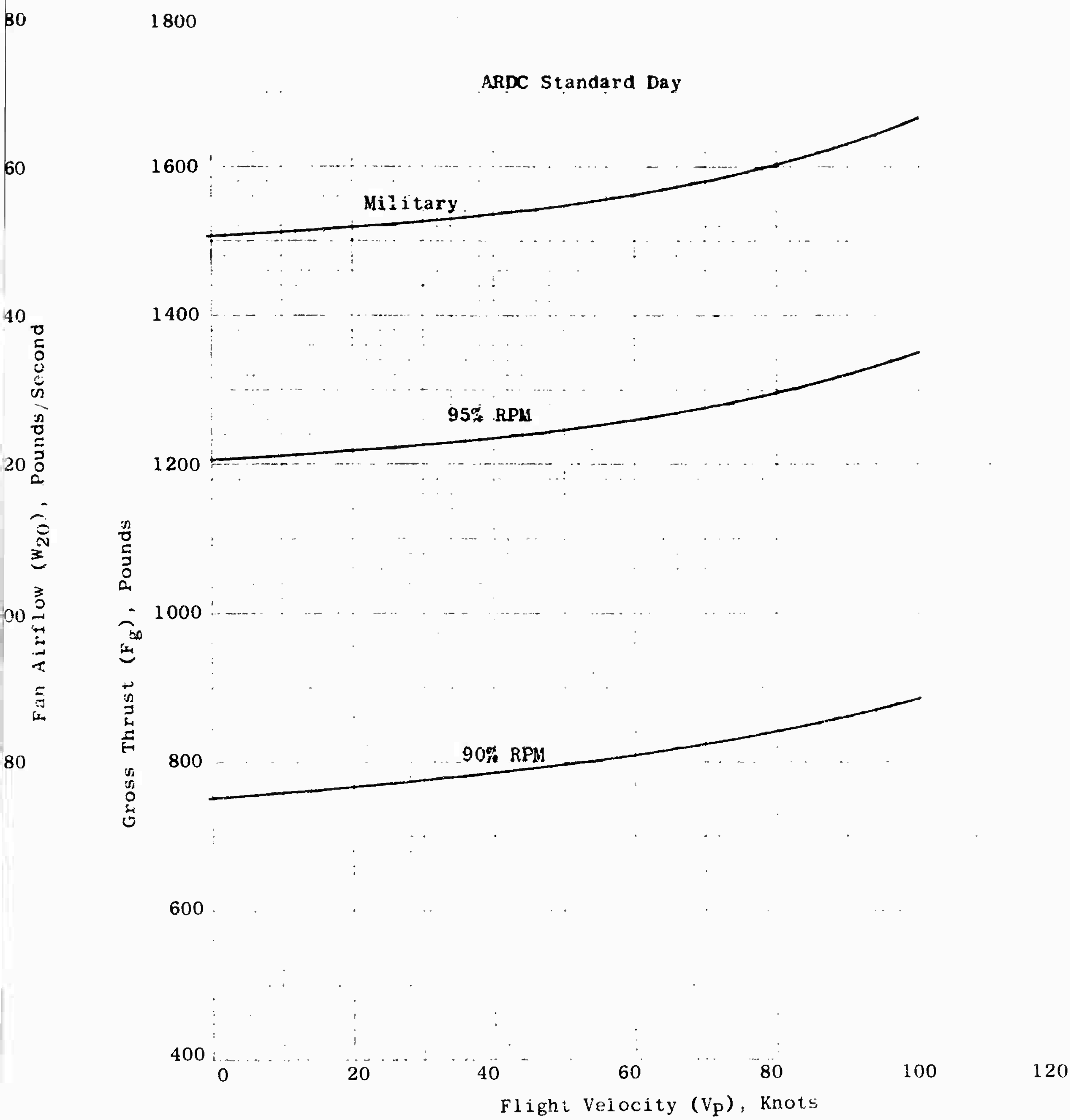


Figure 2. Gross Thrust Vs. Flight Velocity Design Lift Setting - 3000 Ft. Altitude

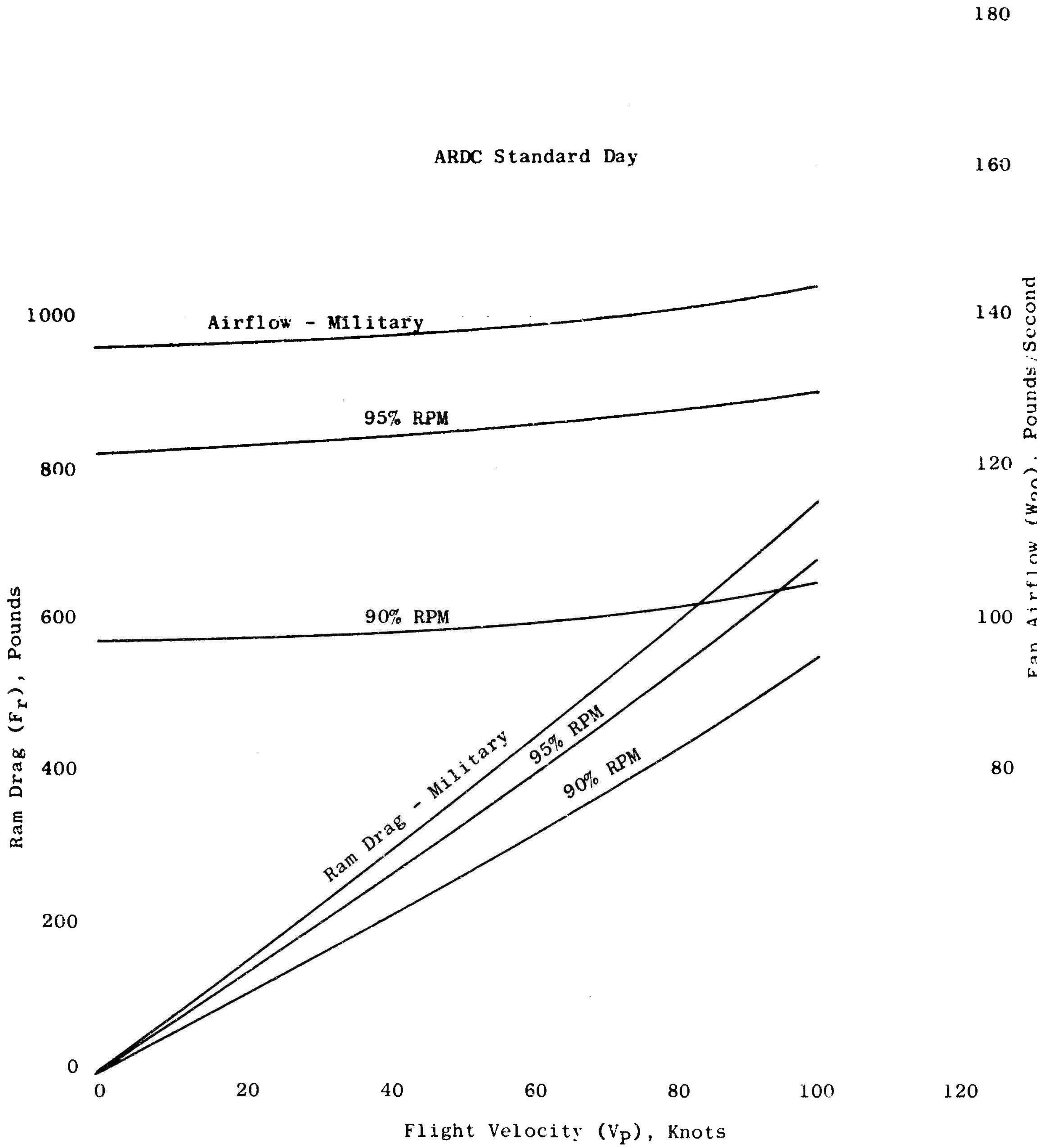


Figure 2a. Ram Drag And Airflow Vs. Flight Velocity Design Lift Setting 3000 Ft. Altitude

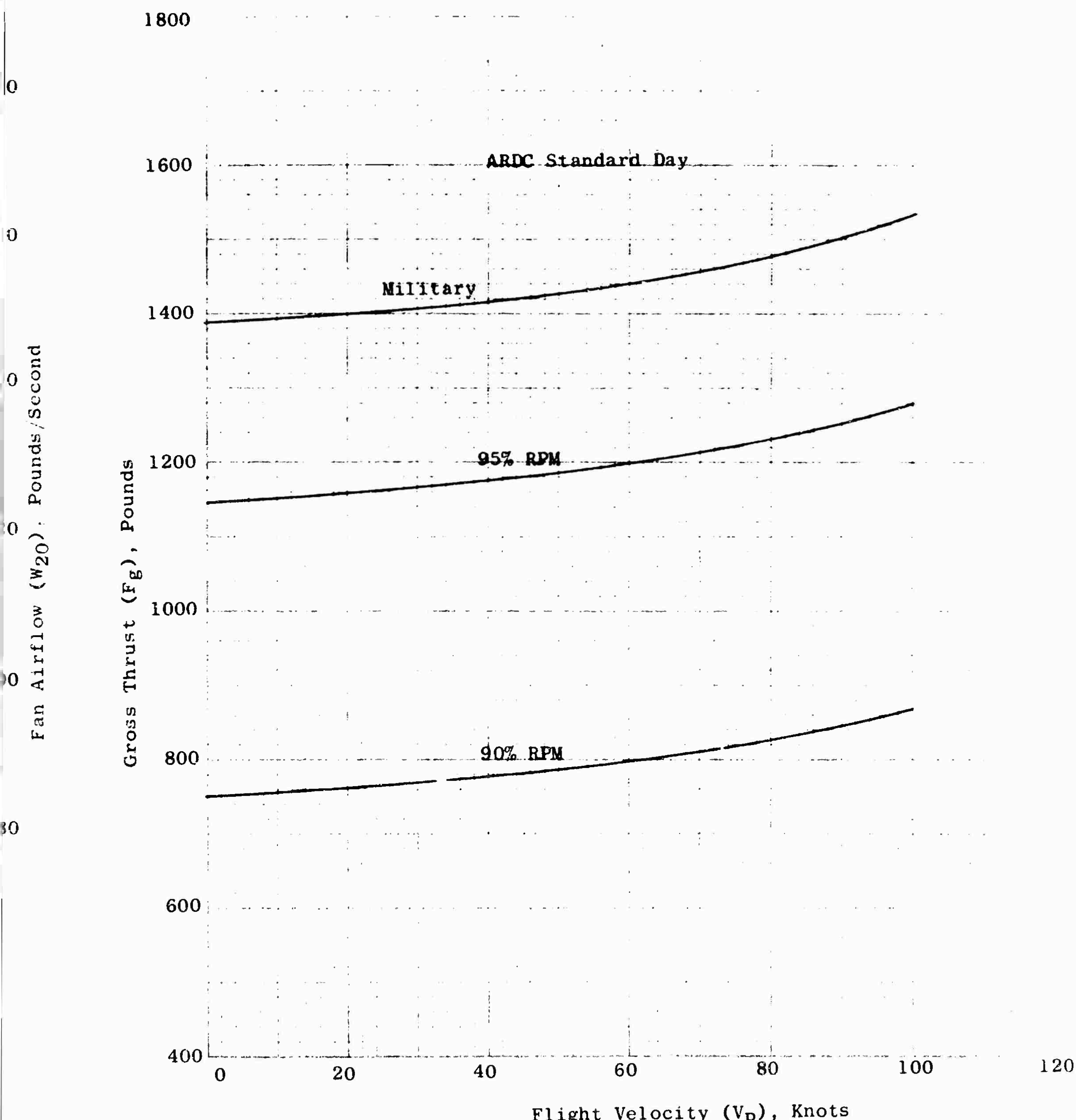


Figure 3. Gross Thrust Vs. Flight Velocity Design Lift Setting - 6000 Ft. Altitude

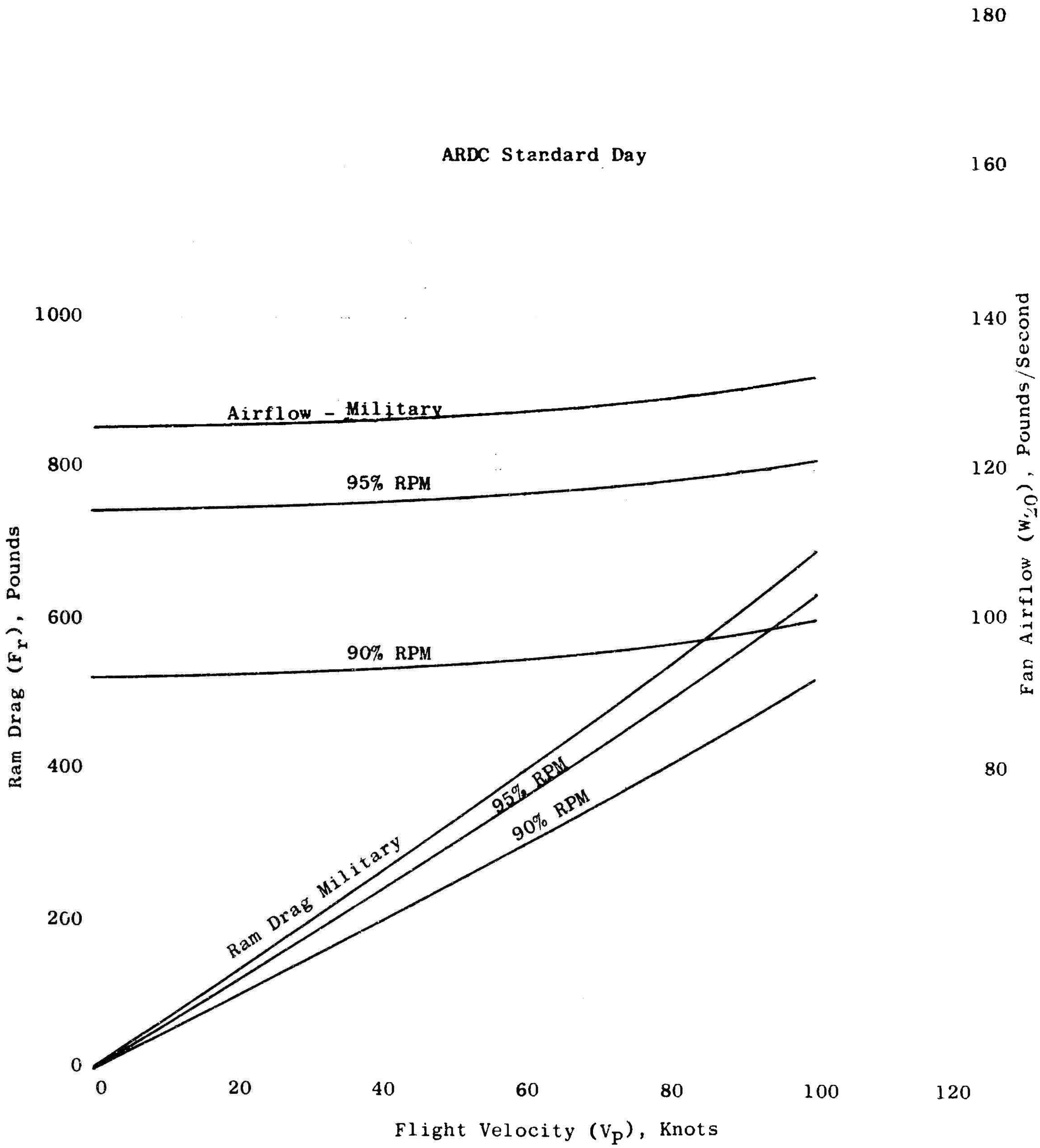


Figure 3a. Ram Drag And Airflow Vs. Flight Velocity Design Lift Setting 6000 Ft. Altitude

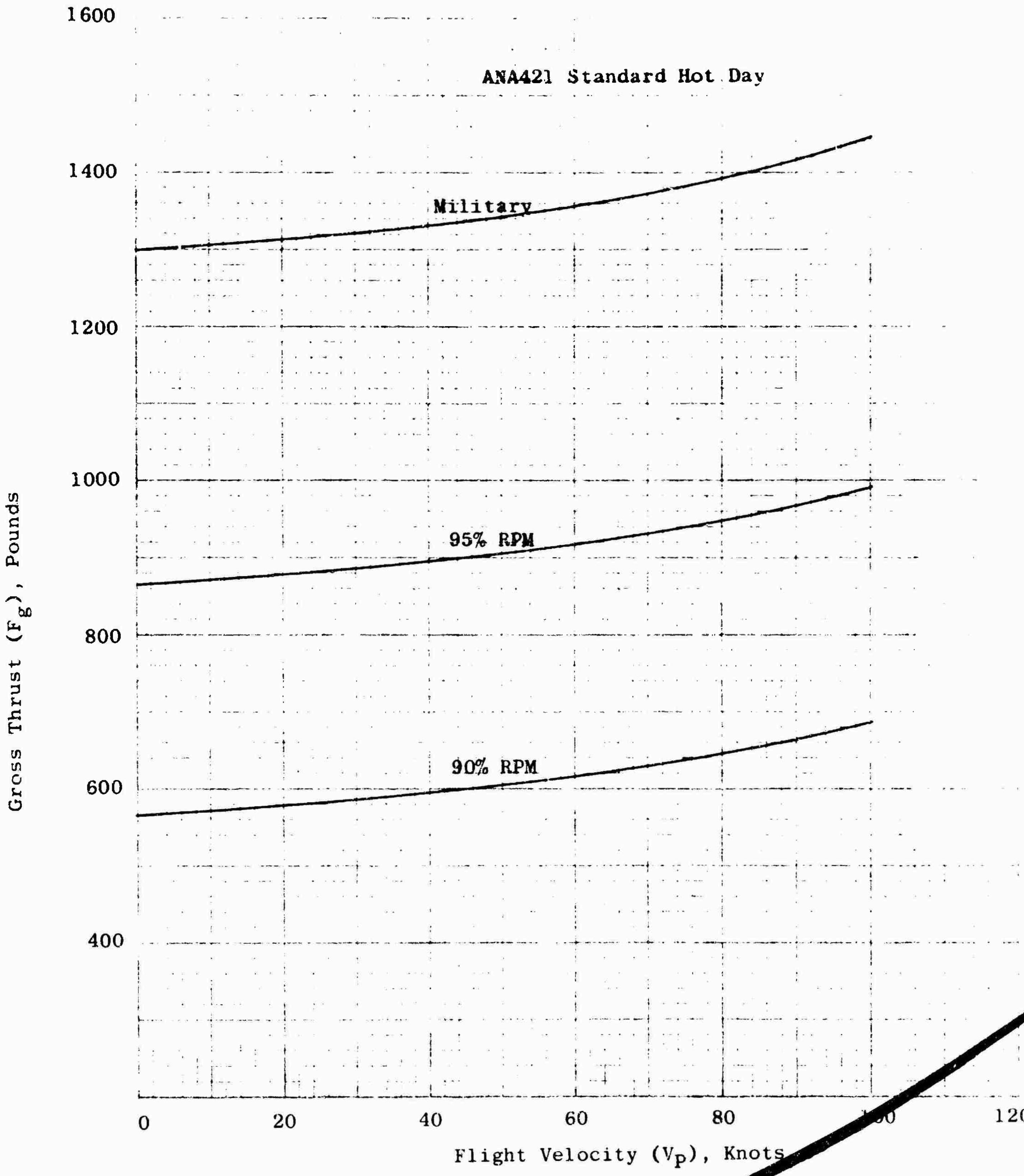


Figure 4. Gross Thrust Vs. Flight Velocity Design Lift Setting - 2500 Ft. Altitude

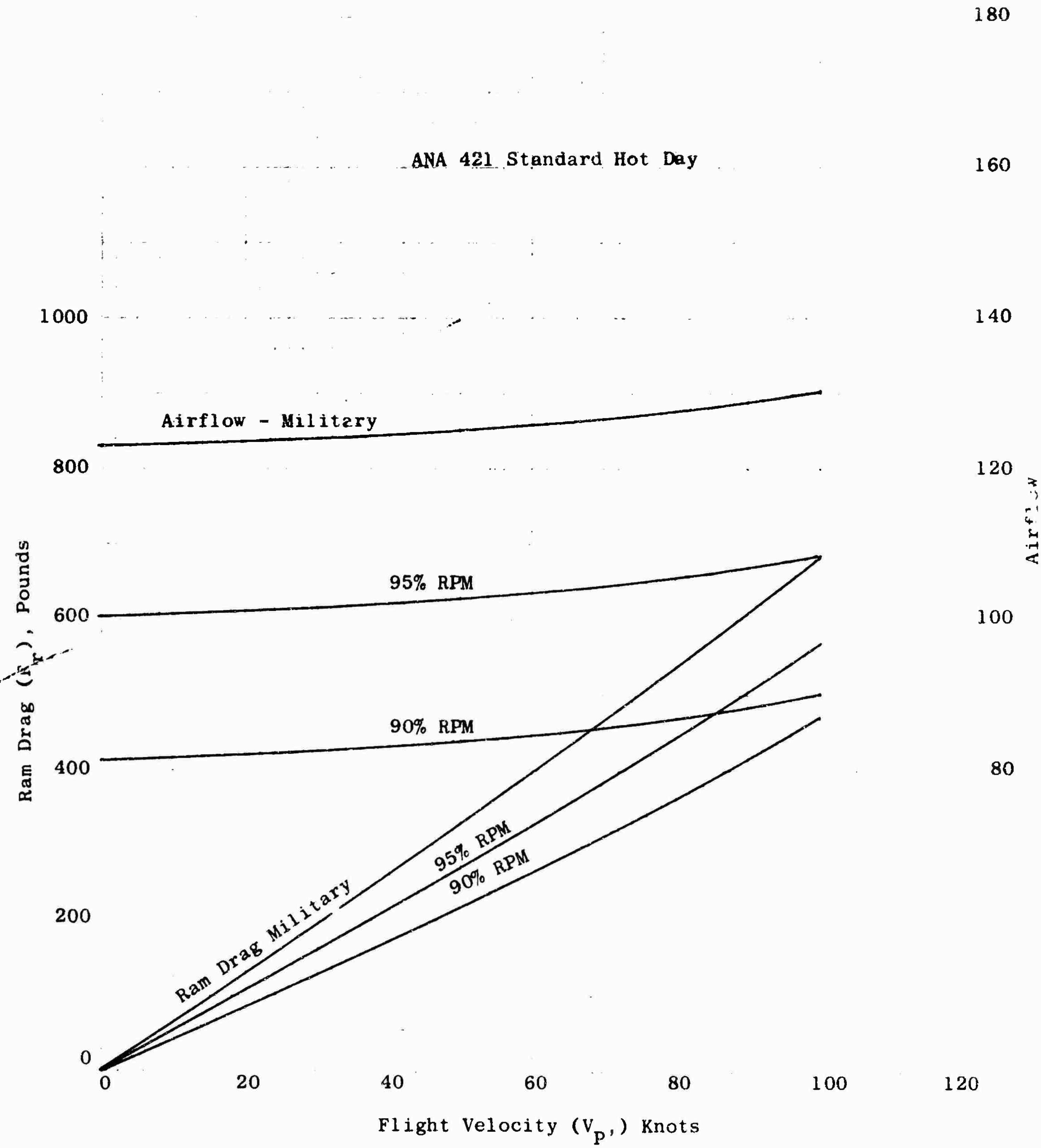


Figure 4a. Ram Drag And Airflow Vs Flight Velocity Design Lift Setting 2500 Ft. Altitude

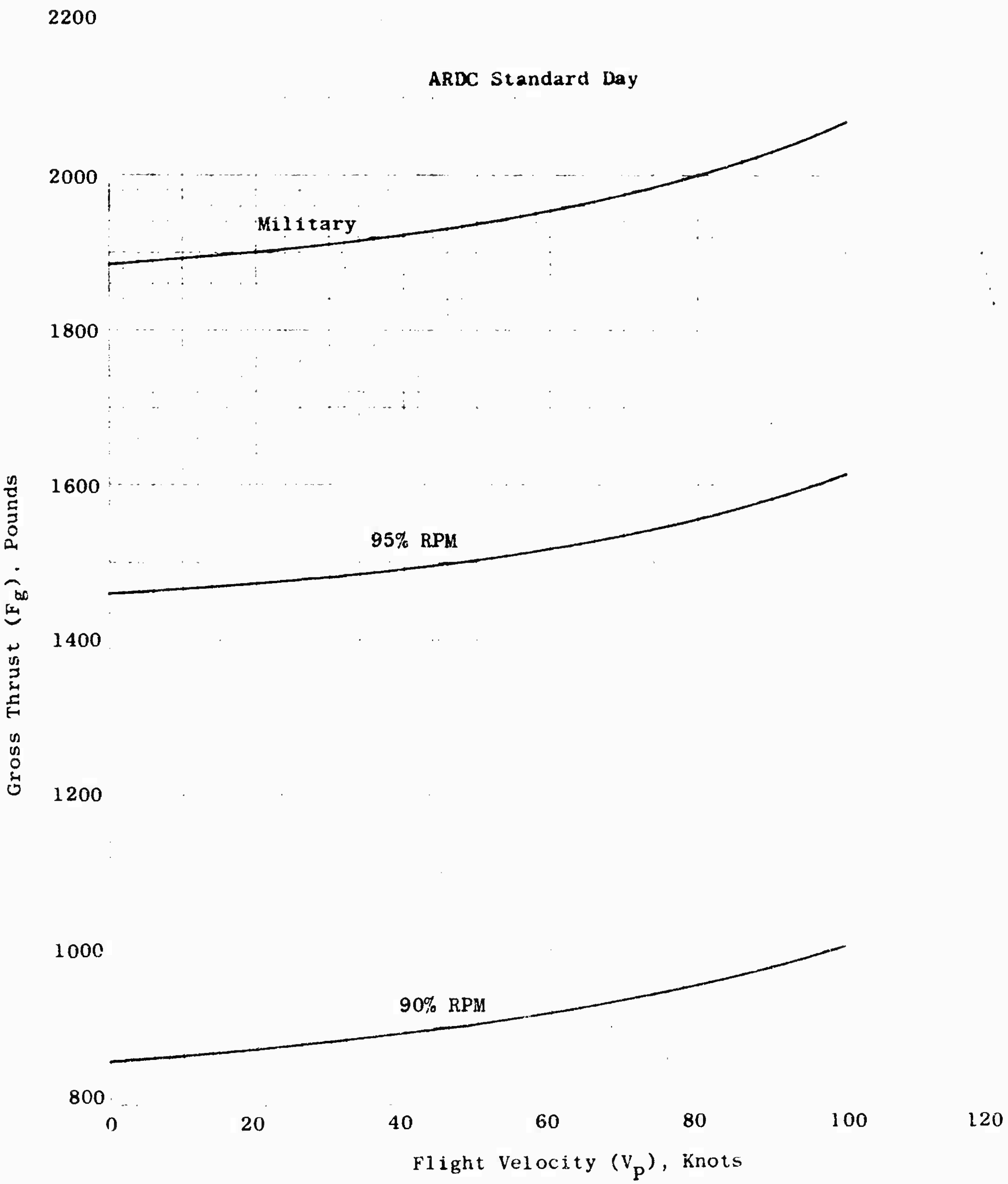


Figure 5. Gross Thrust Vs. Flight Velocity High Lift Setting - Sea Level

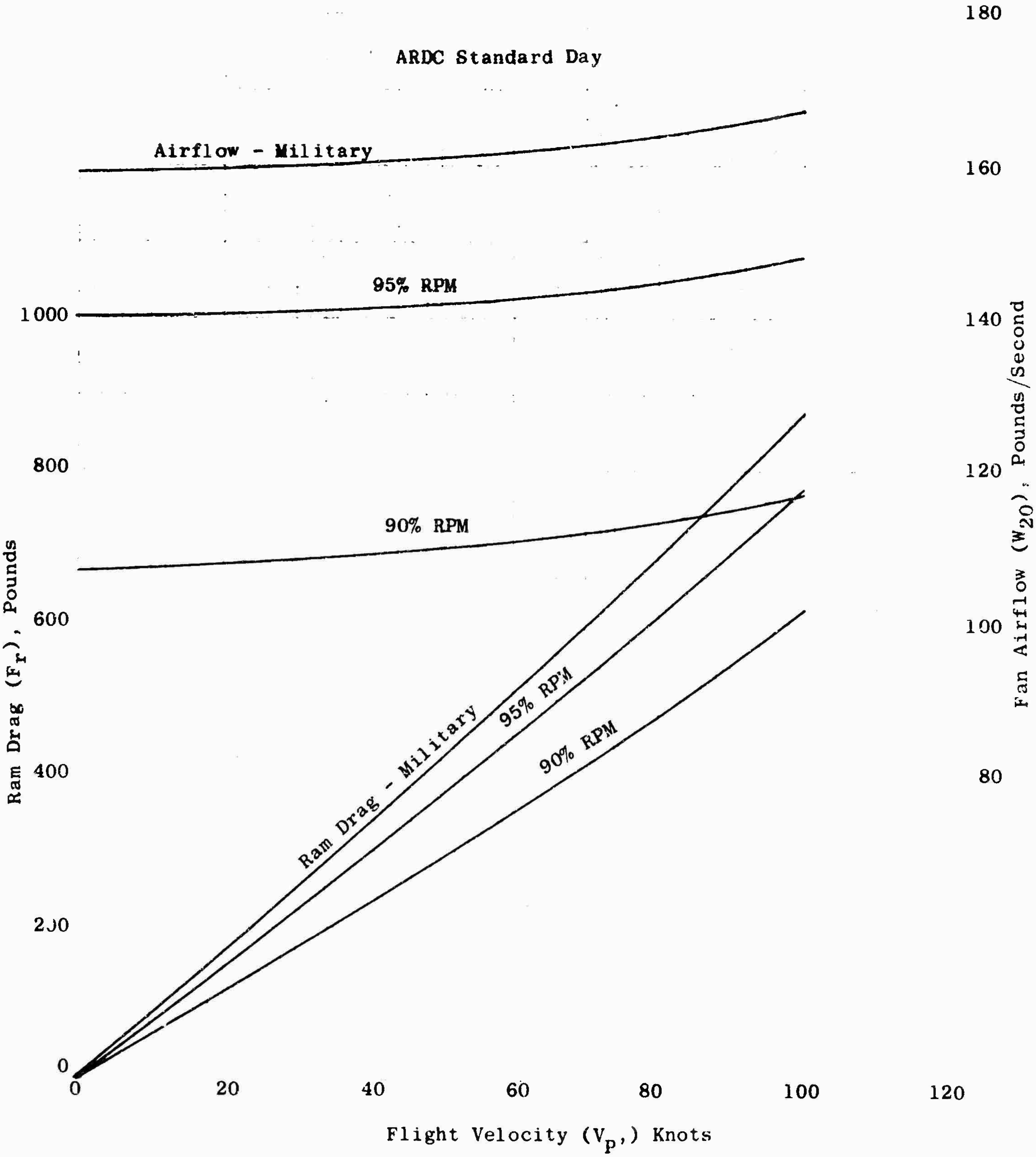


Figure 5a. Ram Drag And Airflow Vs. Flight Velocity High Lift Setting Sea Level

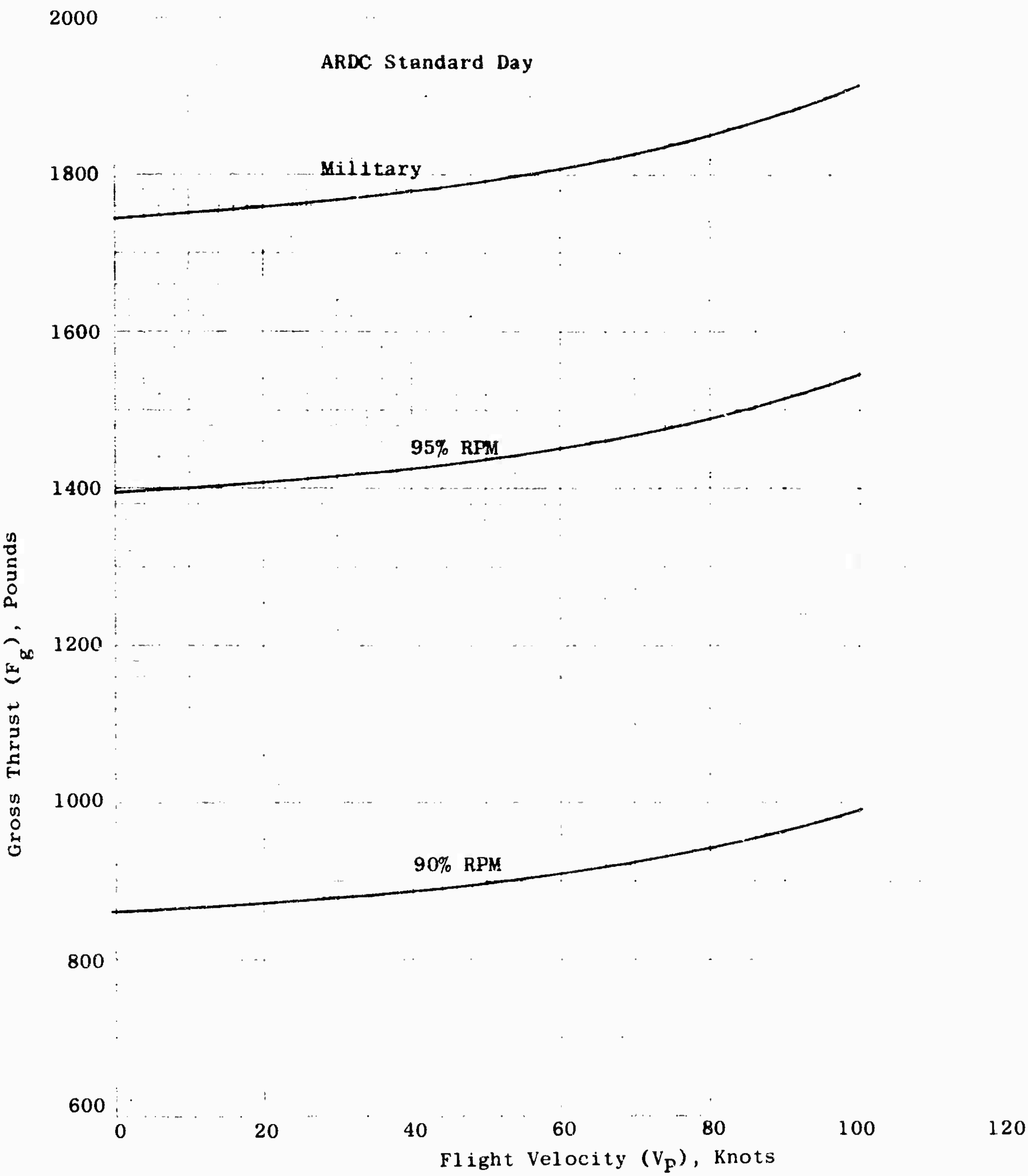


Figure 6 . Gross Thrust Vs. Flight Velocity High Lift Setting - 3000 Ft. Altitude

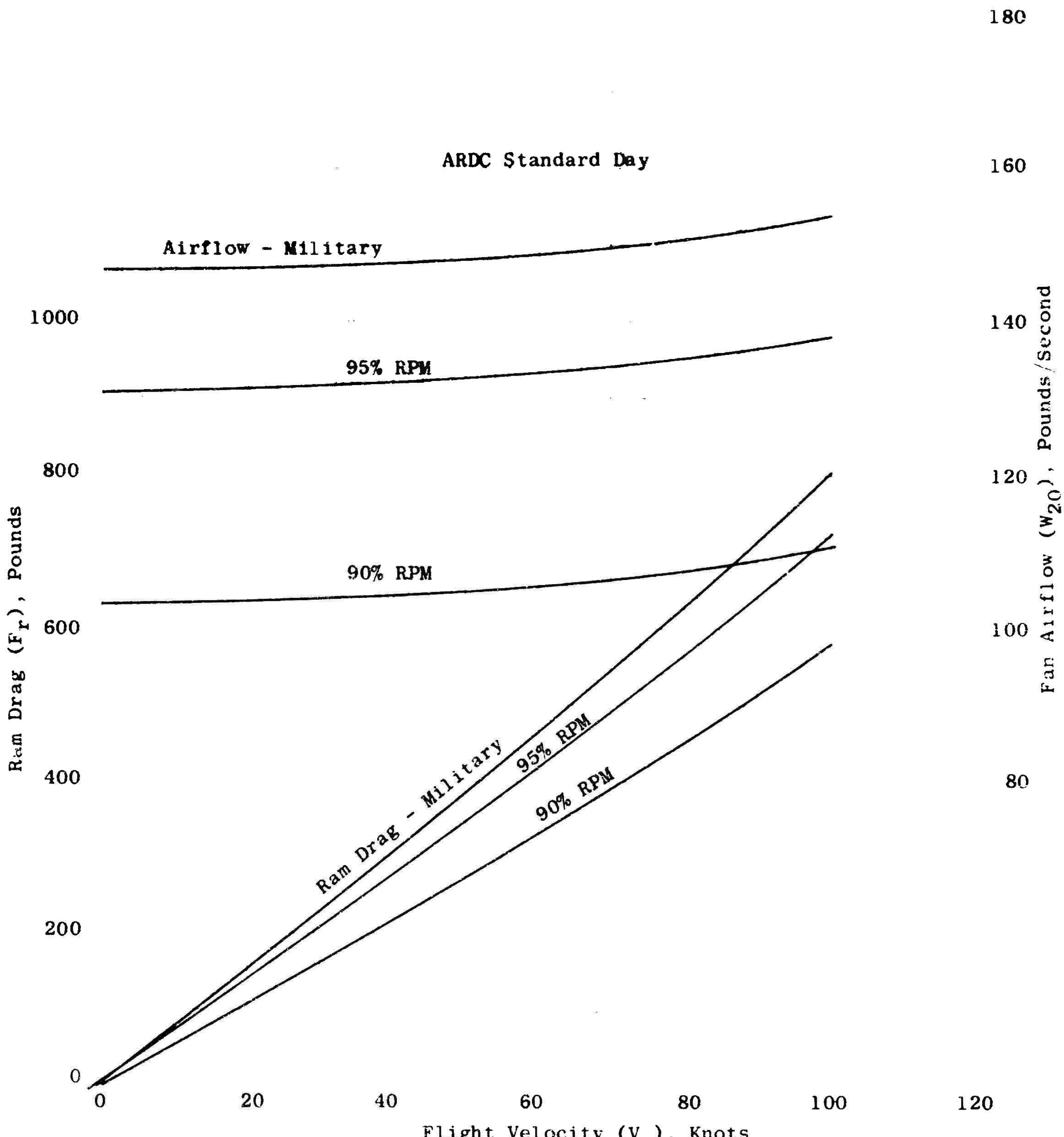


Figure 6a. Ram Drag And Airflow Vs. Flight Velocity High Lift Setting 3000 Ft. Altitude

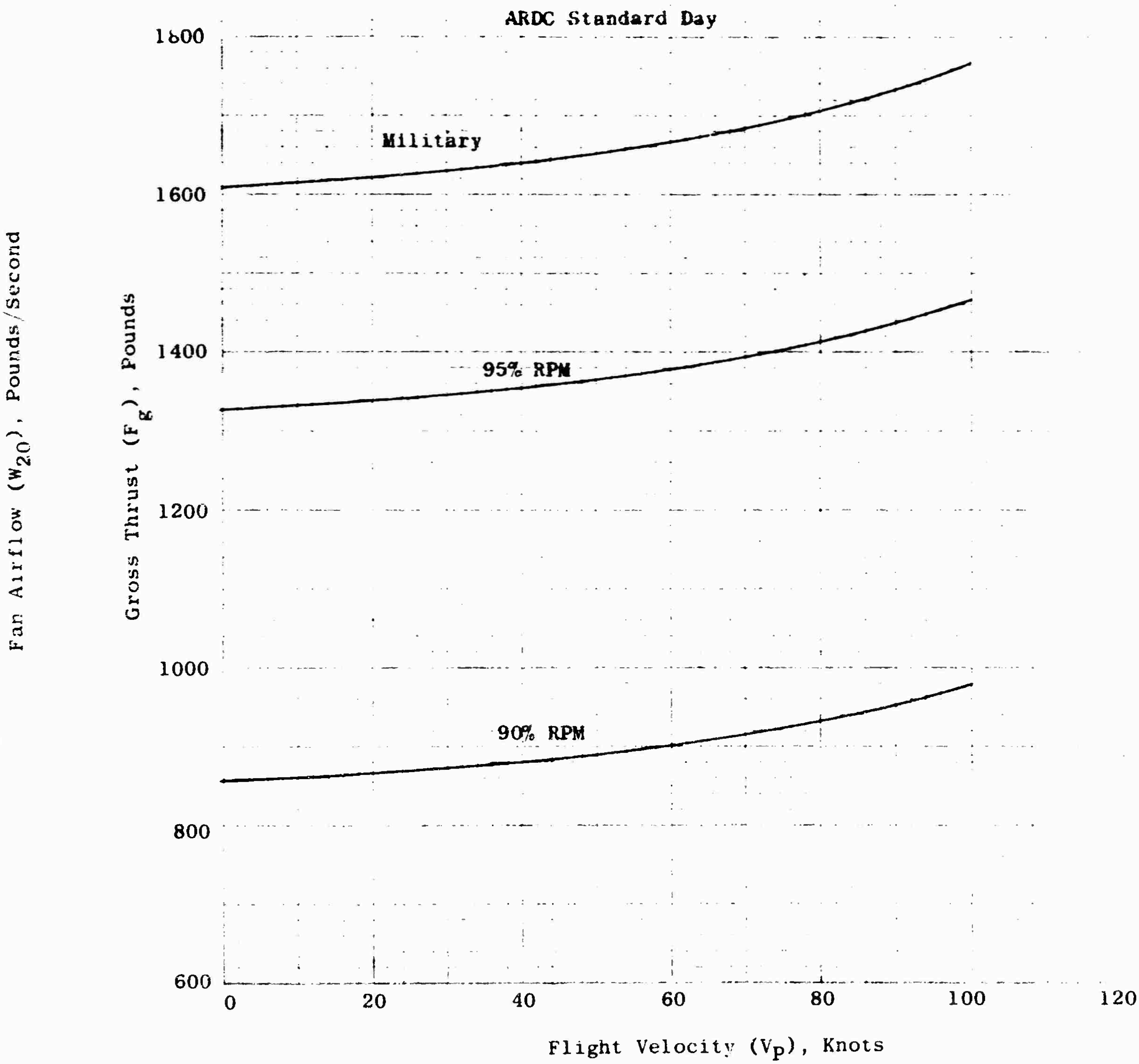


Figure 7. Gross Thrust Vs. Flight Velocity High Lift Setting - 6000 Ft. Altitude

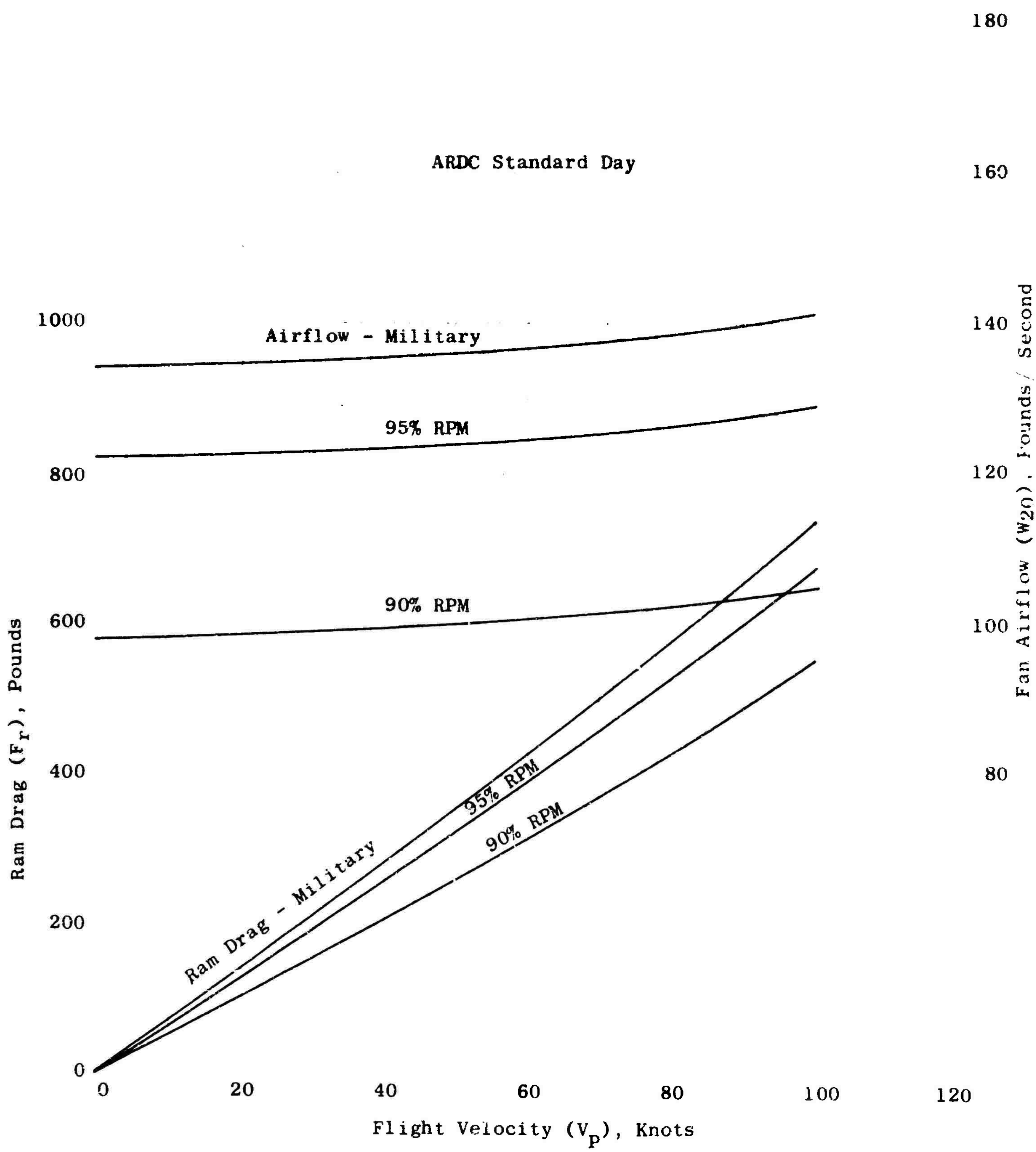


Figure 7a. Ram Drag And Airflow Vs. Flight Velocity High Lift Setting
6000 Ft. Altitude

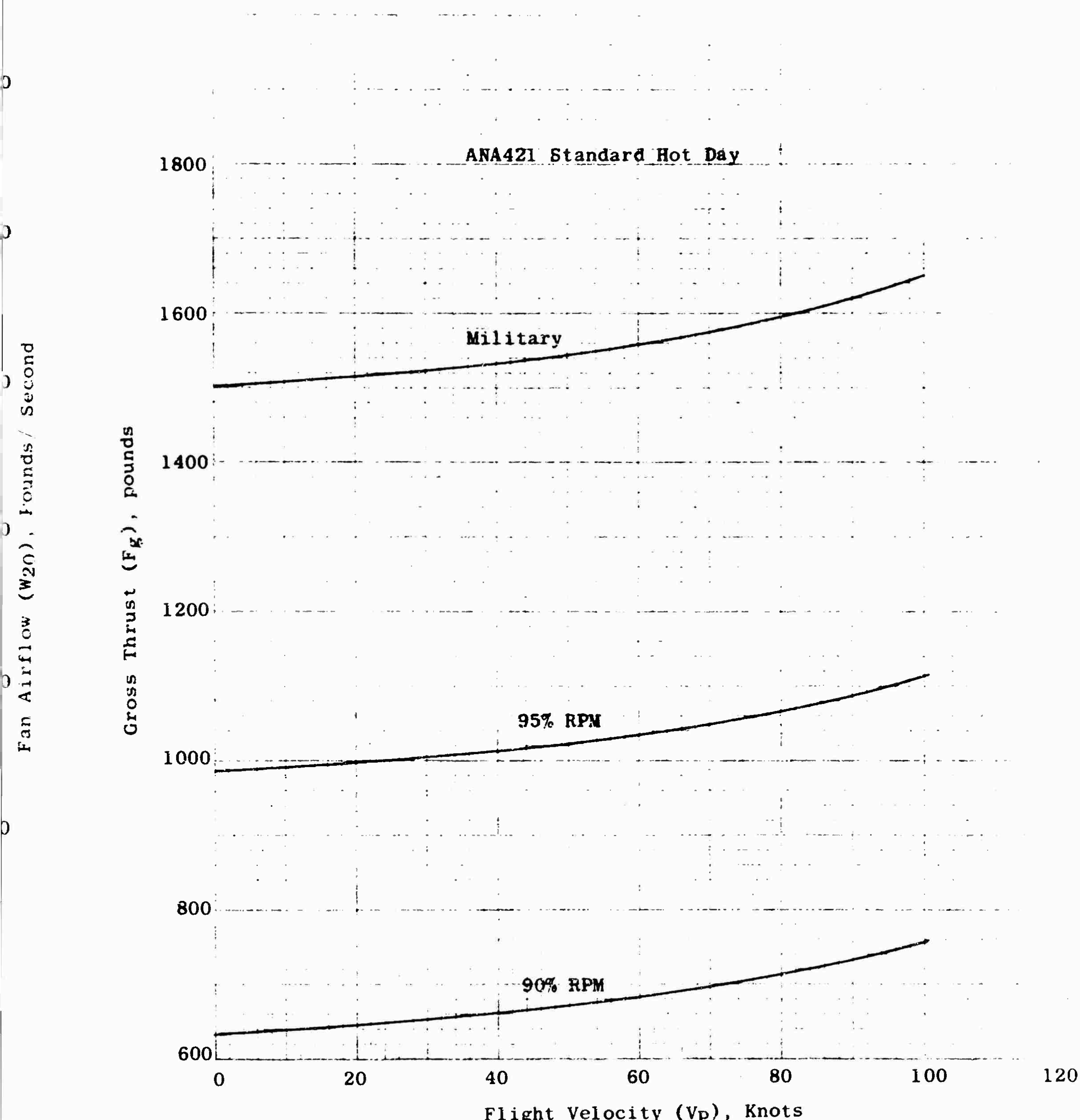


Figure 8.. Gross Thrust Vs. Flight Velocity High Lift Setting 2500 Ft. Altitude

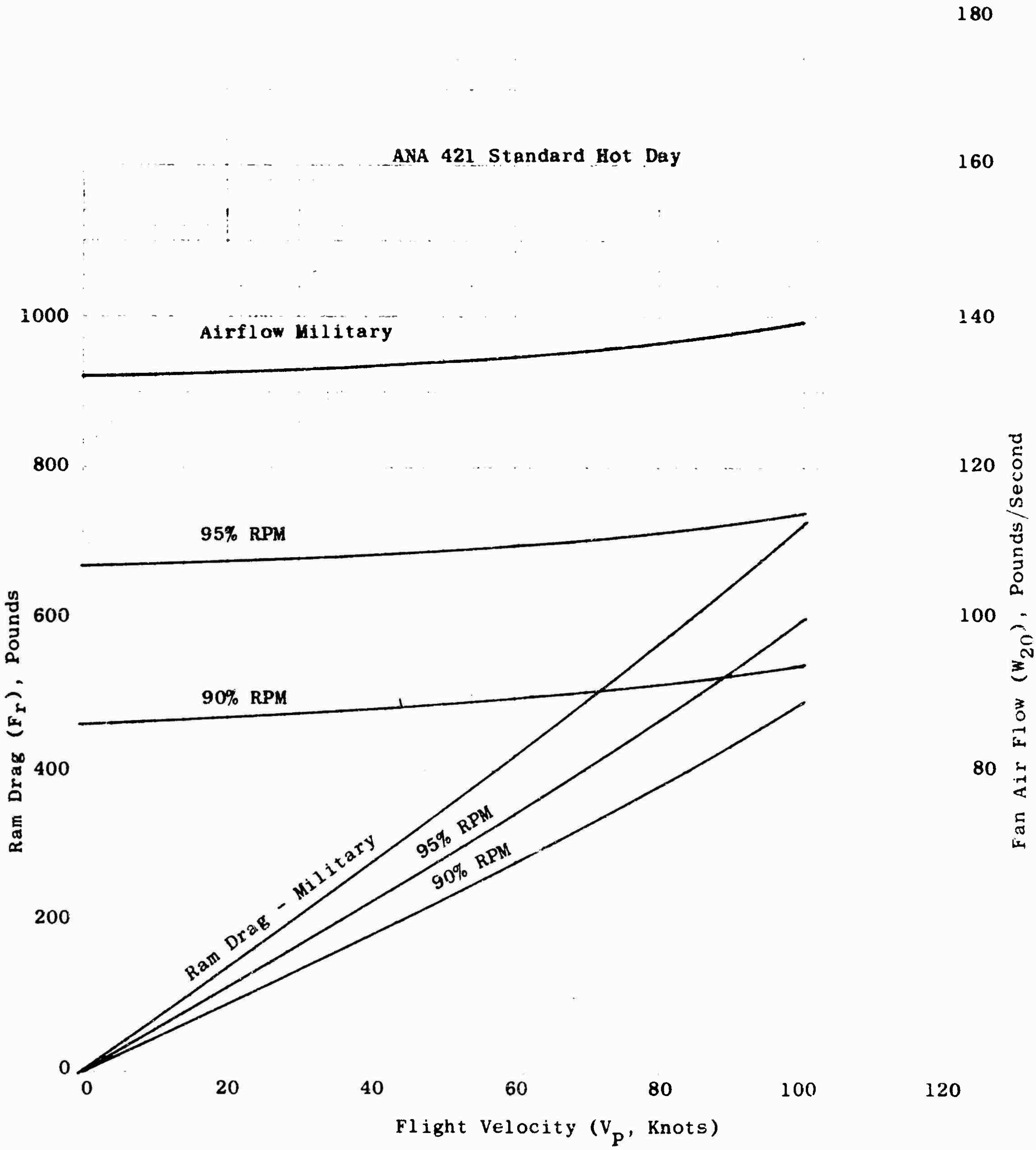


Figure 8a. Ram Drag And Airflow Vs. Flight Velocity High Lift Setting 2500 Ft. Altitude

TABLE V

CORRECTION FACTORS TO DESIGN SETTING LIFT PERFORMANCE

(For Correction Of Performance At High Lift Setting
These Are Only Approximately Correct)

SYMBOL	USE	VALUE	RANGE
Δ_1	Ambient Temperature Correction Factor to Gross Thrust	See Figure 9	$\pm$ 0 - 60^o
Δ_2	Ambient Temperature Correction Factor to Ram Drag	See Figure 9	$\pm$ 0 - 60^o
Δ_3	Fan Inlet Velocity Head Loss Correction Factor to Gross Thrust	-0.0057	0 - 30%
Δ_4	Fan Inlet Velocity Head Loss Correction Factor to Ram Drag	-0.0034	0 - 30%
Δ_5	Additional Gas Ducting Pressure Loss Correction Factor to Gross Thrust	-0.0086	0 - 5%
Δ_6	Additional Gas Ducting Pressure Loss Correction Factor to Ram Drag	-0.0045	0 - 5%
Δ_7	Turbojet Inlet Total Pressure Loss Correction Factor to Gross Thrust	-0.0151	0 - 10%
Δ_8	Turbojet Inlet Total Pressure Loss Correction Factor to Ram Drag	-0.0074	0 - 10%
Δ_9	Compressor Discharge Bleed Correction Factor to Gross Thrust	-0.0244	0 - 6%
Δ_{10}	Compressor Discharge Bleed Correction Factor to Ram Drag	-0.0123	0 - 6%
K_1	Gas Supply Correction Factor To Gross Thrust	See Figure 10	9.29-11.61 #/sec
K_2	Gas Supply Correction Factor to Ram Drag	See Figure 11	9.29-11.61 #/sec
C_1	Turbojet Horsepower Extraction Correction Factor to Gross Thrust	-0.0202	0-100 HP
C_2	Turbojet Horsepower Extraction Correction Factor to Ram Drag	-0.0109	0-100 HP

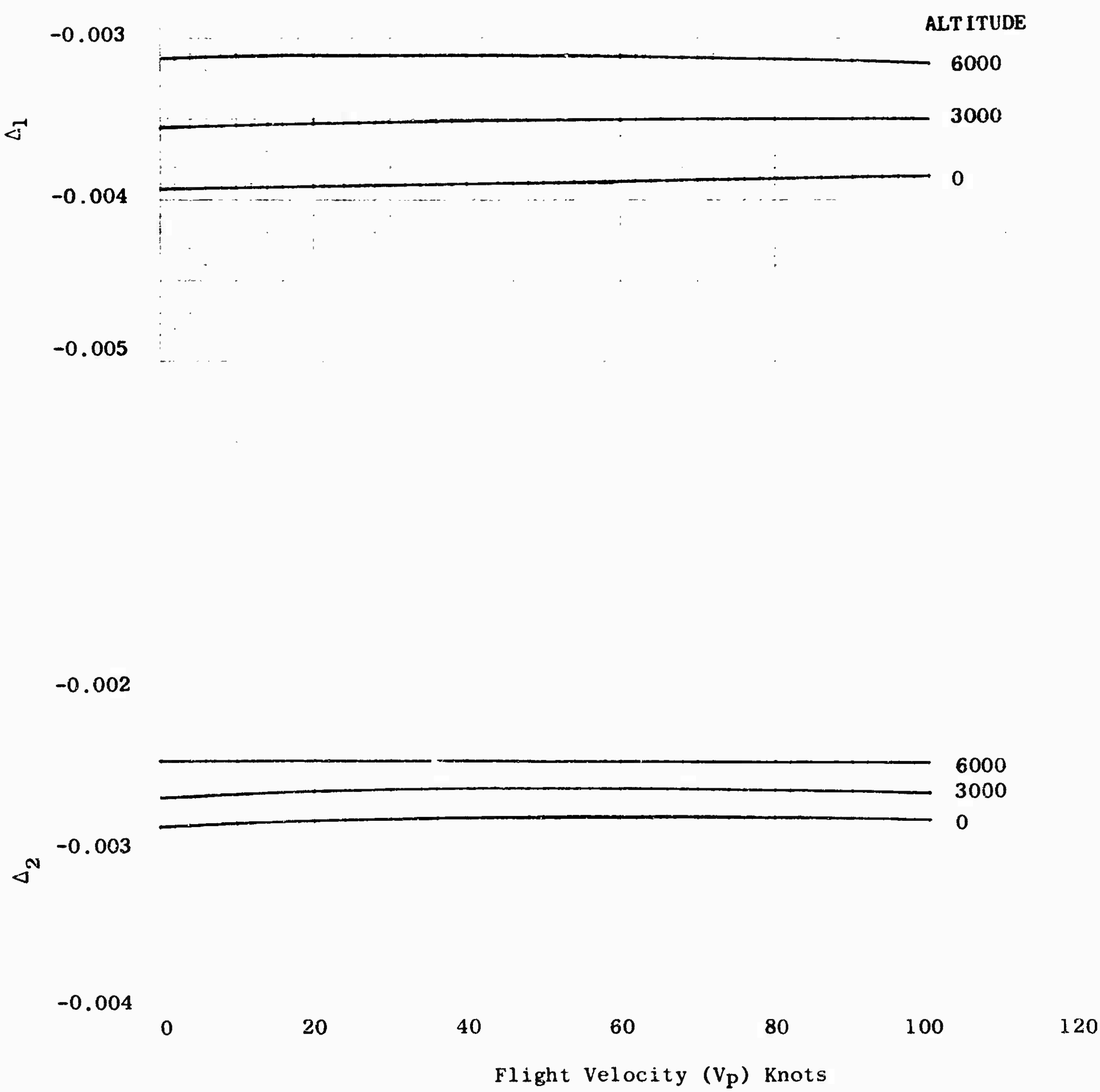


Figure 9. Correction Factors To F_g And F_r For Ambient Temperature

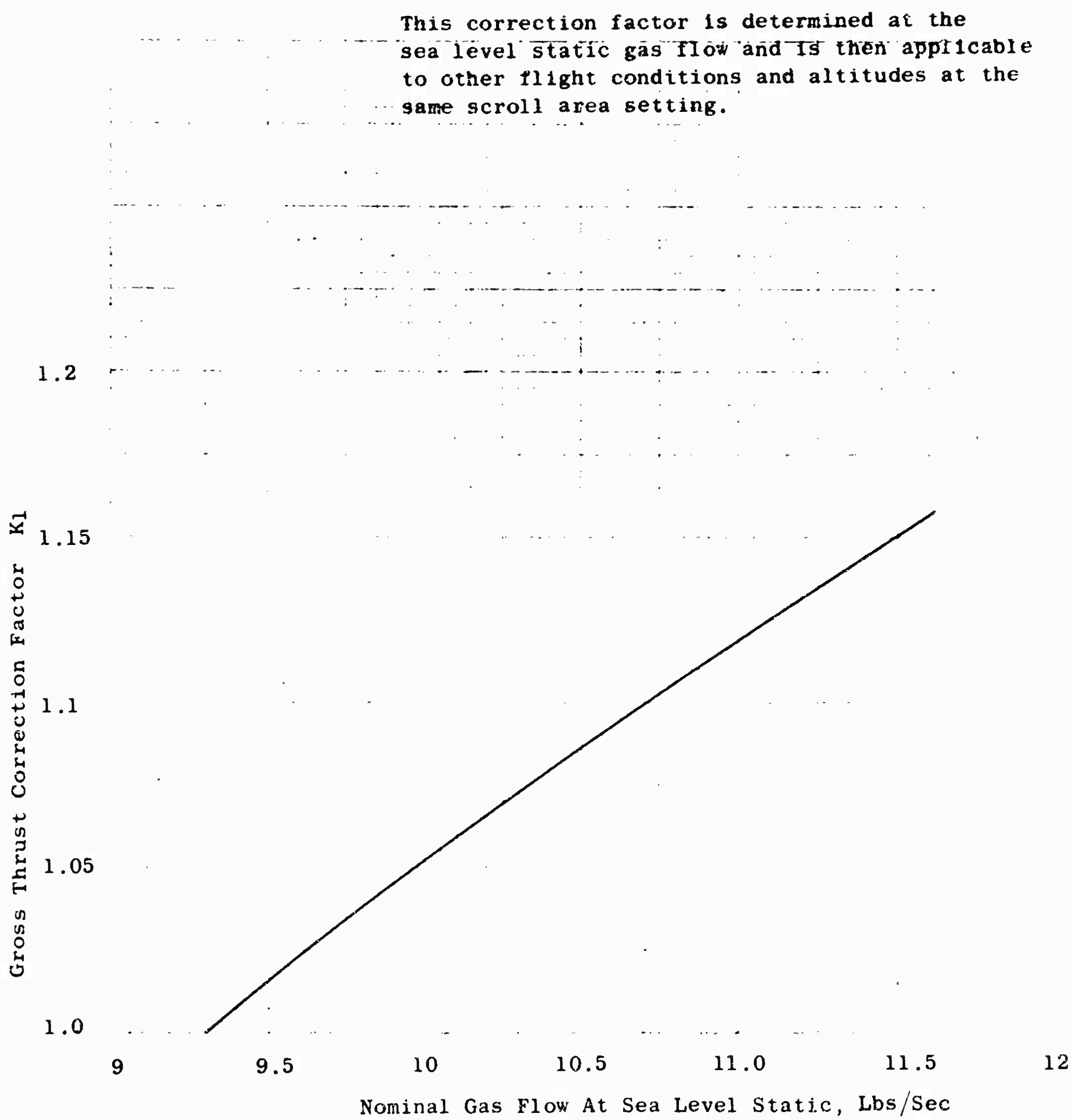


Figure 10. Gross Thrust Correction Factor Vs Nominal SLS Gas Flow

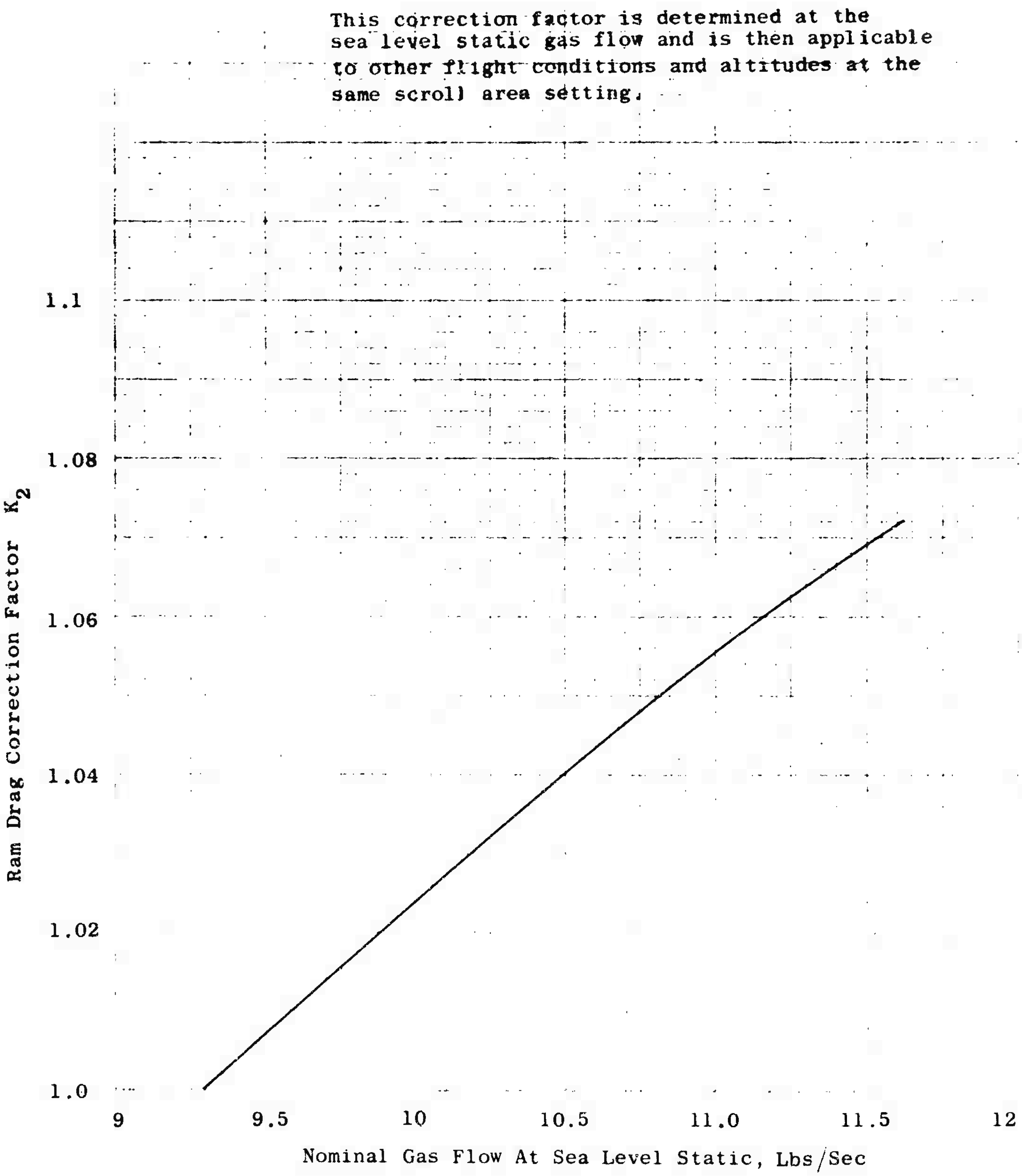


Figure 11. Ram Drag Correction Factor Vs. Nominal SLS Gas Flow

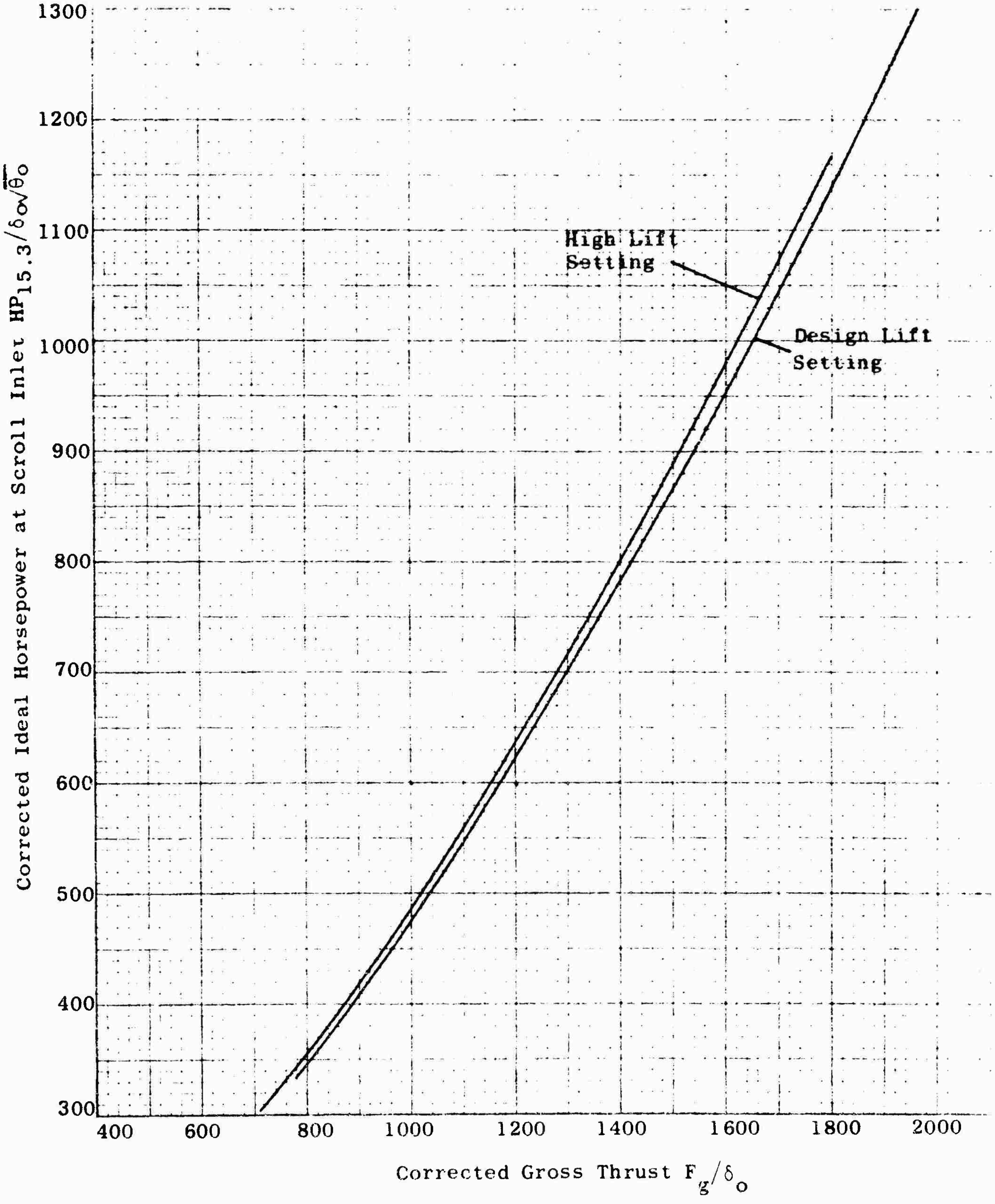


Figure 12. Lift Vs. Scroll Inlet Ideal Horsepower

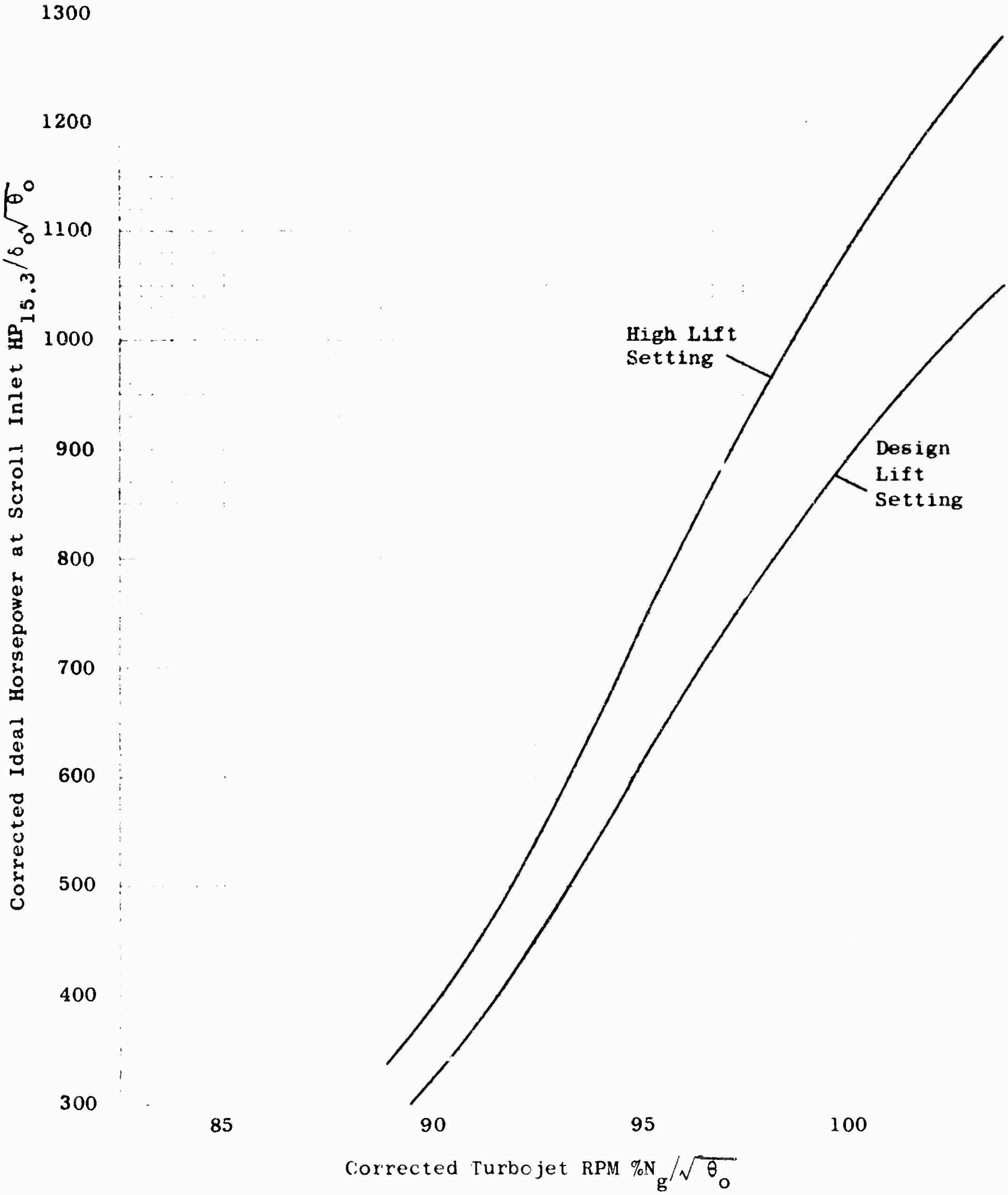


Figure 13. Basic Ideal Horsepower At Scroll Inlet Vs. Turbojet RPM

3.4.5.1.3 <u>Method For Correcting Estimated Performance:</u> The following equations illustrate the use of the correction factors in 3.4.5.1.2 for use in correcting estimated performance as shown in paragraph 3.4.5.1. Subscript c is used to denote the corrected value.

Bleed Gas Supply Correction

1. $F_{gc} = F_g (K_1)$

2. $F_{rc} = F_r (K_2)$

Ambient Temperature Correction

3. $F_{gc} = F_g [1 + \Delta_1 (T_{am} - T_s)]$

4. $F_{rc} = F_r [1 + \Delta_2 (T_{am} - T_s)]$

Internal Loss Correction

5. $F_{gc} = F_g [1 + \Delta_n (\% \text{ loss})]$; n = 3, 5, 7, 9

6. $F_{rc} = F_r [1 + \Delta_n (\% \text{ loss})]$; n = 2, 4, 6, 8

Gas Generator Horsepower Extraction

7. $F_{gc} = F_g [1 + C_1 (\text{HP extracted}/100)]$

8. $F_{rc} = F_r [1 + C_2 (\text{HP extracted}/100)]$

Ideal Horsepower at Scroll Inlet

9. $$(HP_{15.3})_{Ideal} = \frac{778}{550} T_{15.3} C_{p\,15.3} \left[1 - \left(\frac{P_{am}}{P_{15.3}} \right)^{\frac{\gamma - 1}{\gamma}} \right] W_{15.3}$$

SAMPLE CALCULATIONS:

The correction factors are of three types, K corrections, Δ corrections and C corrections. All corrections of each type are handled in a similar fashion as shown below:

1. Corrections by K factors

   Example: Gas Supply Correction (K_1, K_2)

   Assume: Altitude = 3000 feet

   Power Setting = Military

   V_P = 50 Knots

   Scroll area set for nominal gas supply of 10.5 lbs/sec at Sea Level Static

   $F_{g_1} = F_g\ (K_1)$

   From Figure 2 @ 50 Knots, Military power,

   read $F_g = 1550$

   From Figure 10 @ nominal gas supply of 10.5

   read $K_1 = 1.087$

   $F_{g_1} = (1550)\ (1.087)$

   $= (1685)$

   $F_{r_1} = F_r\ (K_2)$

   From Figure 2a @ 50 knots, Military power

   read $F_r = 365$

   From Figure 11 @ nominal gas supply of 10.5 lbs/sec

   read $K_2 = 1.0405$

   $F_r = (365)\ (1.0405)$

   $= (380)$

2. Corrections by Δ factors

The product of the Δ factor times the change in the variable is the percent change in the basic performance number.

Example: Ambient temperature corrections (Δ_1, Δ_2)

Assume: Same conditions as 1 above except $T_{am} = 90^{o}F$

$$F_{g_2} = F_{g_1} \left[1 + (\Delta_1)\ T_{am} - T_s)\right]$$

From Figure 9 @ 3000 ft. altitude, 50 knots

read $\Delta_1 = -0.0035$

$$F_{g_2} = (1685) \left[1 + (-0.0035)\ (90 - 48.3)\right]$$

$$= 1439$$

$$F_{r_2} = F_{r_1} \left[1 + (\Delta_2)\ (T_{am} - T_s)\right]$$

From Figure 9 @ 3000 ft. altitude, 50 knots

read $\Delta_2 = -0.00265$

$$F_{r_2} = (380) \left[1 + (-0.00265)\ (90 - 48,3)\right]$$

$$= 338$$

3. Corrections by C correction factors

The product of the C factor times the ratio of the change to an arbitrary basic change in the variable is the percent change in the basic performance number.

Example: Turbojet horsepower extraction correction (C_1, C_2)

Assume: Same conditions as in 2 above, except horsepower extracted = 25 hp

$$F_{g_3} = F_{g_2} \left[1 + C_1\ (\text{HP extracted}/100)\right]$$

From table of correction factors (Table V)

read $C_1 = -0.0202$

$$F_{g_3} = (1439)\left[1 + (-0.0202)\ (25/100)\right]$$

$$= 1432$$

$$F_{r_3} = F_{r_2}\left[1 + C_2\ (\text{HP extracted}/100)\right]$$

From table of correction factors (Table V) read $C_2 = -0.0109$

$$F_{r_3} = (338)\left[1 + (-0.0109)\ (25/100)\right]$$

$$= 337$$

3.4.5.3 Electronic Automatic Machine Performance Presentation: Performance presentation with electronic automatic machine is furnished in the "X376 Customer Deck", for IBM 7090 computer.

3.4.6 Altitude - Temperature limits for flight starting and operating: Not applicable.

3.4.6.1 Sea Level Operating Limits Turbojet Mode: Not Applicable

3.4.6.2 Flight Starting Limits Turbojet Mode: Not Applicable.

3.4.6.3 Altitude - Temperature limits for lift-mode operation: The estimated lift-mode operating limits curves are shown in Figures 14 and 15

3.4.6.4 Absolute Altitude: Not applicable

3.4.6.10 Reverse Thrust: The X376 Pitch Fan is designed such that it can be used in conjunction with a modulated thrust reversing device at the fan discharge. Such a device or attachment is not a part of the pitch fan. For each individual installation it is necessary for the General Electric Company and the airframe manufacturer to jointly establisn compatibility between the pitch fan and the thrust reversing device to assure satisfactory operation.

3.4.11 Thrust Transients. All times specified below are based on the time required to accomplish 95 percent of the change safely based on a control lever movement in one second or less.

3.4.11.2 Thrust Transients, Lift Mode: The total time required to accelerate from idle conditions to maximum fan rpm available is estimated to not exceed six (6) seconds. The total time required to decelerate from maximum fan rpm available to idle conditions is estimated to not exceed four (4) seconds. Estimated transients are shown in Figure 16. Estimated transient performance for small turbojet power setting changes (ninety-five percent fan lift plus and minus five percent fan lift) is shown in Figure 17.

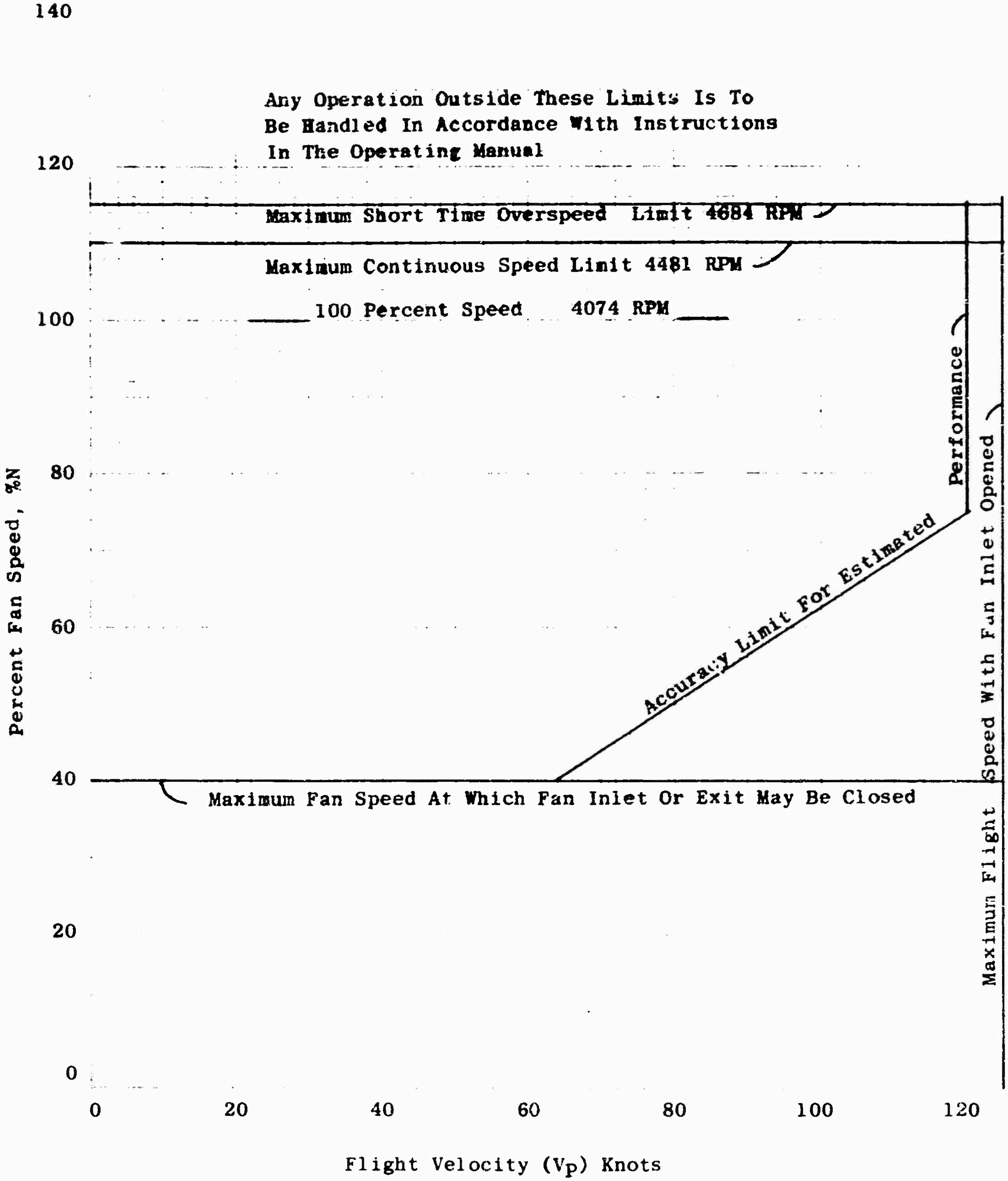


Figure 14. X376 Pitch Fan Operating Limits

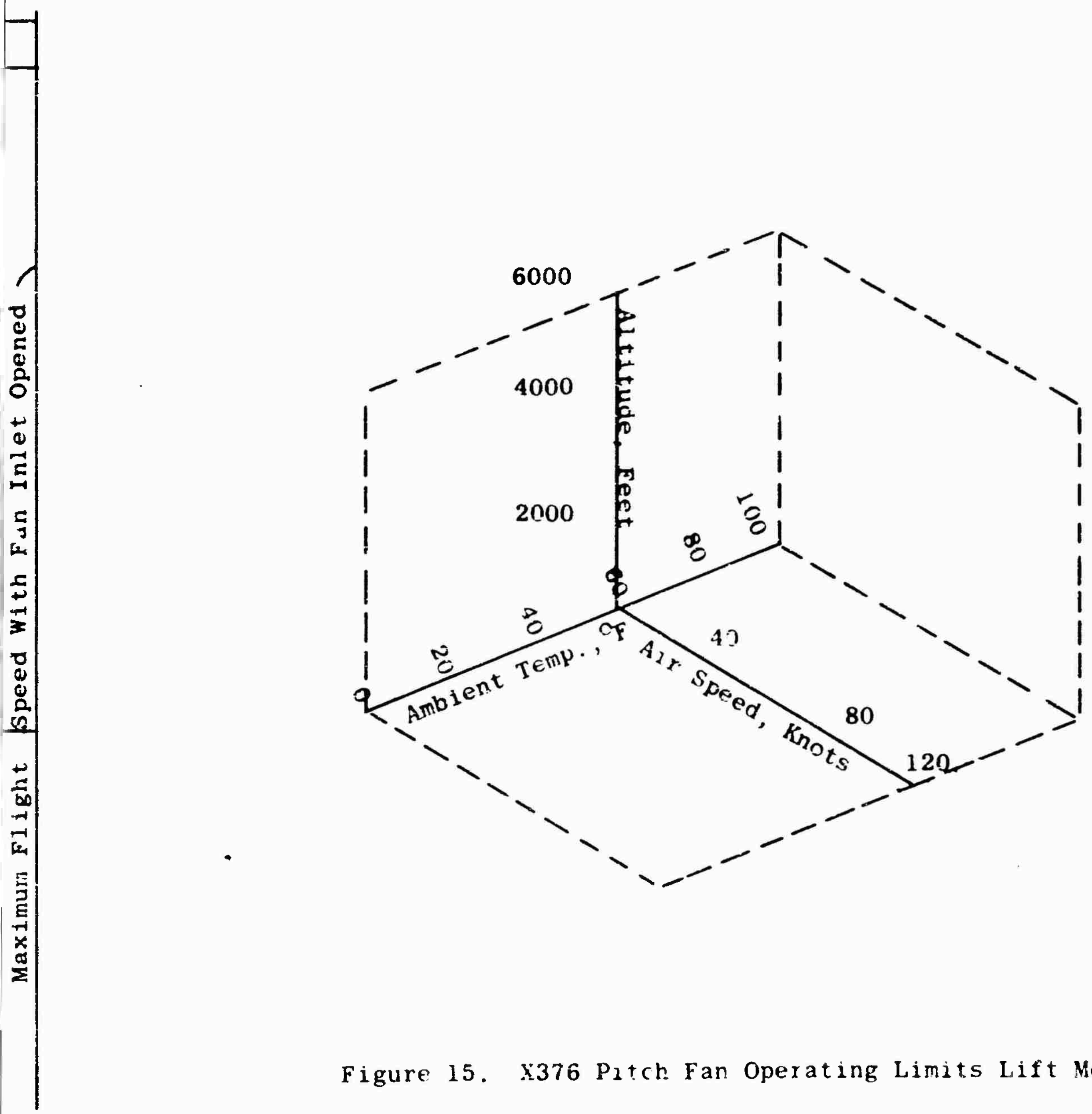


Figure 15. X376 Pitch Fan Operating Limits Lift Mode

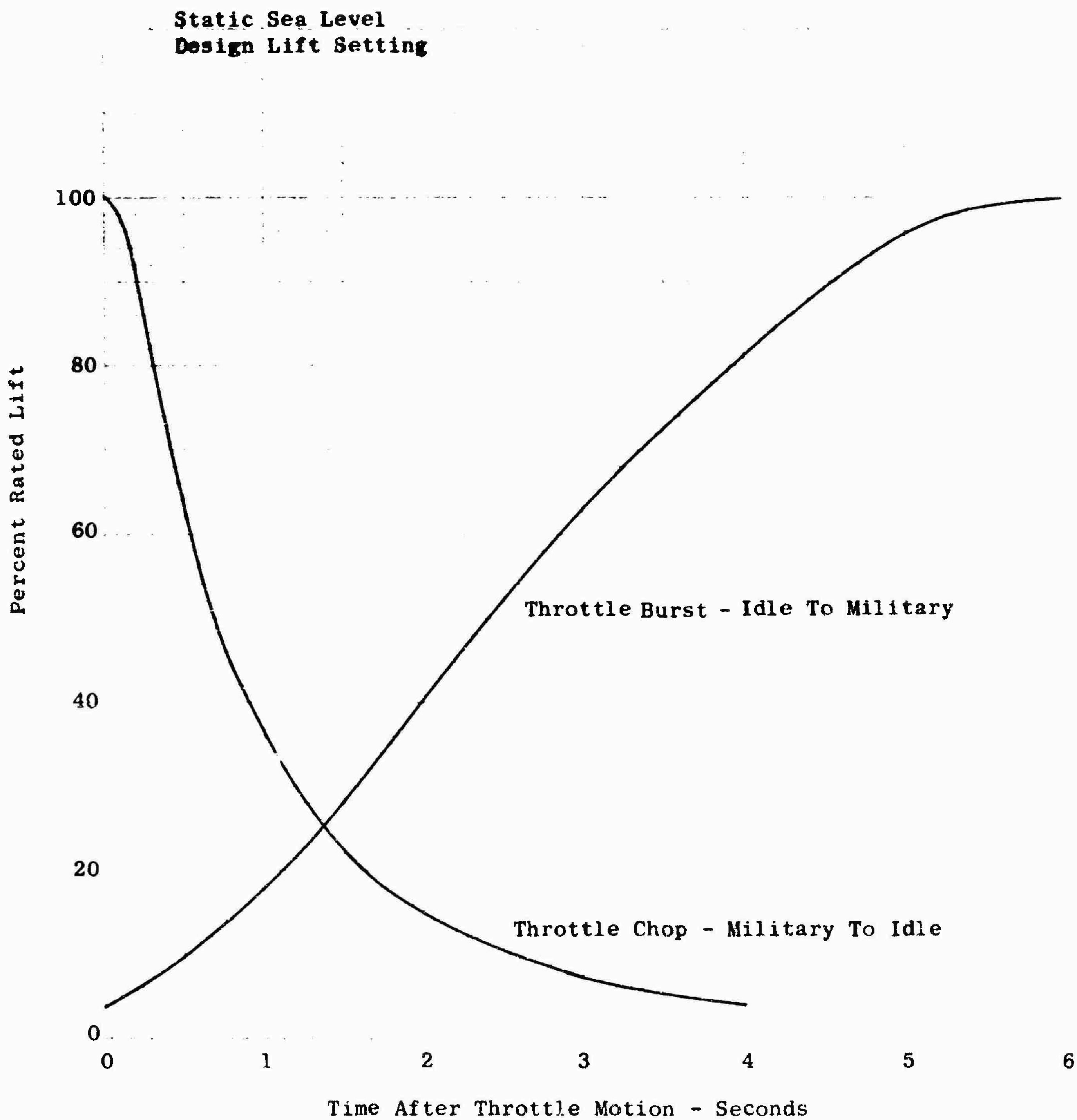


Figure 16. Estimated Transient Performance In Response To Turbojet Throttle Burst And Chop

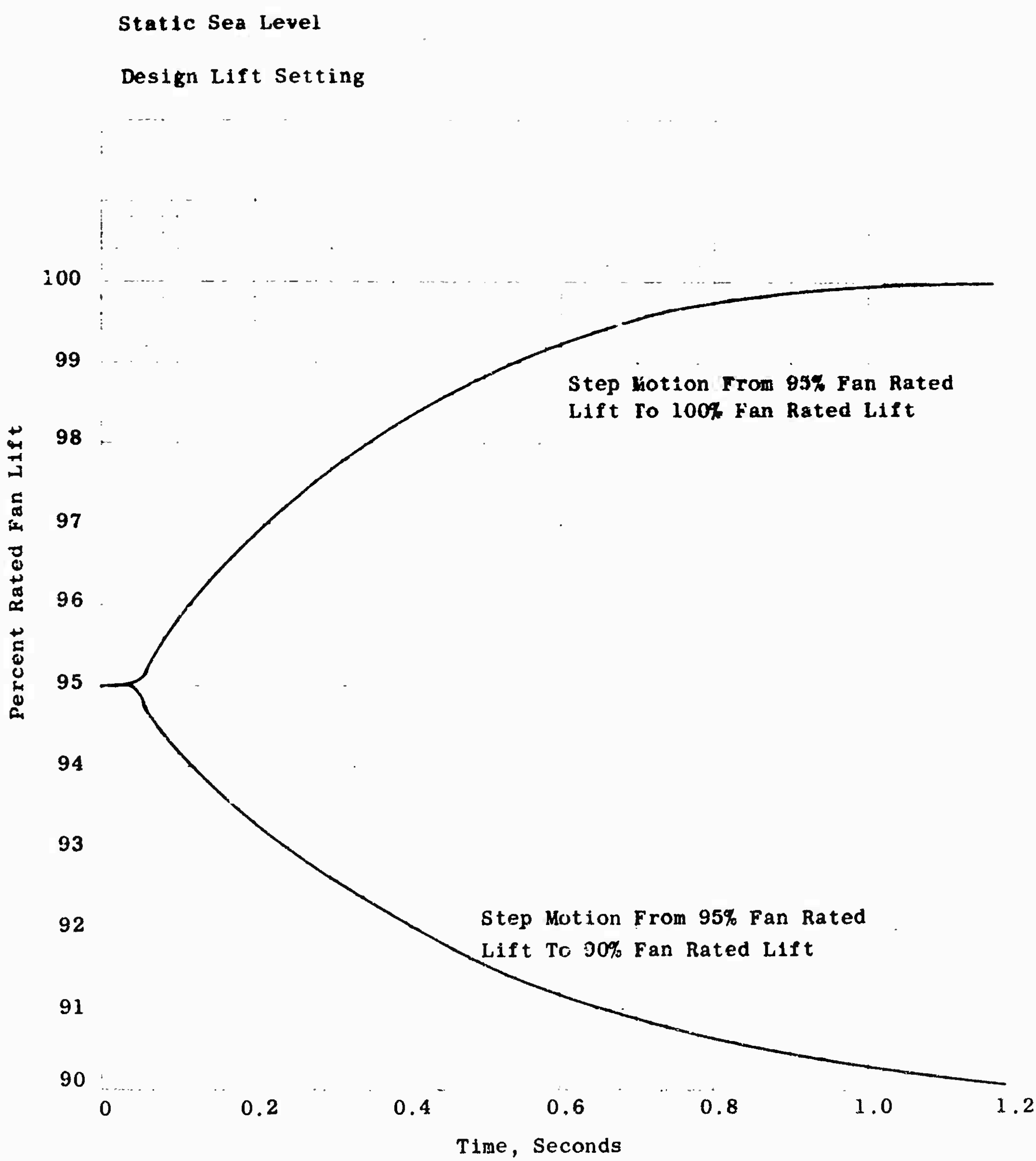


Figure 17. Estimated Transient Performance In Response To Step Motion Of Turbojet Throttle

3.4.11 3 Thrust Transients, Conversions: Conversions to or from powered-fan operation may be accomplished by introduction or removal of full available drive gas power at the scroll inlet in one second or less. Under these conditions the total time required to accelerate the pitch fan from zero rpm to maximum fan rpm available is estimated not to exceed three (3) seconds. The total time required to decelerate from maximum fan rpm available to zero fan rpm is estimated not to exceed four (4) seconds. Estimated transients are shown in Figure 18.

3.4.12 Stability: Not applicable.

3.4.15 Measured Gas Temperature: The maximum allowable continuous gas temperature shall be 1250 degrees F.

The maximum allowable measured transient gas temperature shall be as follows:

Transient Duration	Temperature, ^{o}F
20 seconds	1300
10 seconds	1390
5 seconds	1550
0 seconds	1800

3.4.15.1 Measurement: No measurement of gas temperature is made at the pitch fan. Gas temperature is assumed to be the same as turbojet discharge gas temperature during pitch fan operation.

3.4.16.2 Starting Torque and Speed Requirements: Not applicable.

3.4.17 Thrust Indication: Not applicable.

3.5 Materials and Processes: Materials and processes used in the manufacture of the X376 Pitch Fan shall be of high quality, suitable for the purpose.

3.5.1 Critical Materials: The use of critical materials, particularly chromium, cobalt, niobium, molybdenum, nickel and tungsten shall be held to a minimum. Reporting of the gross and net weights of each of these materials required in the construction of the pitch fan shall not be required.

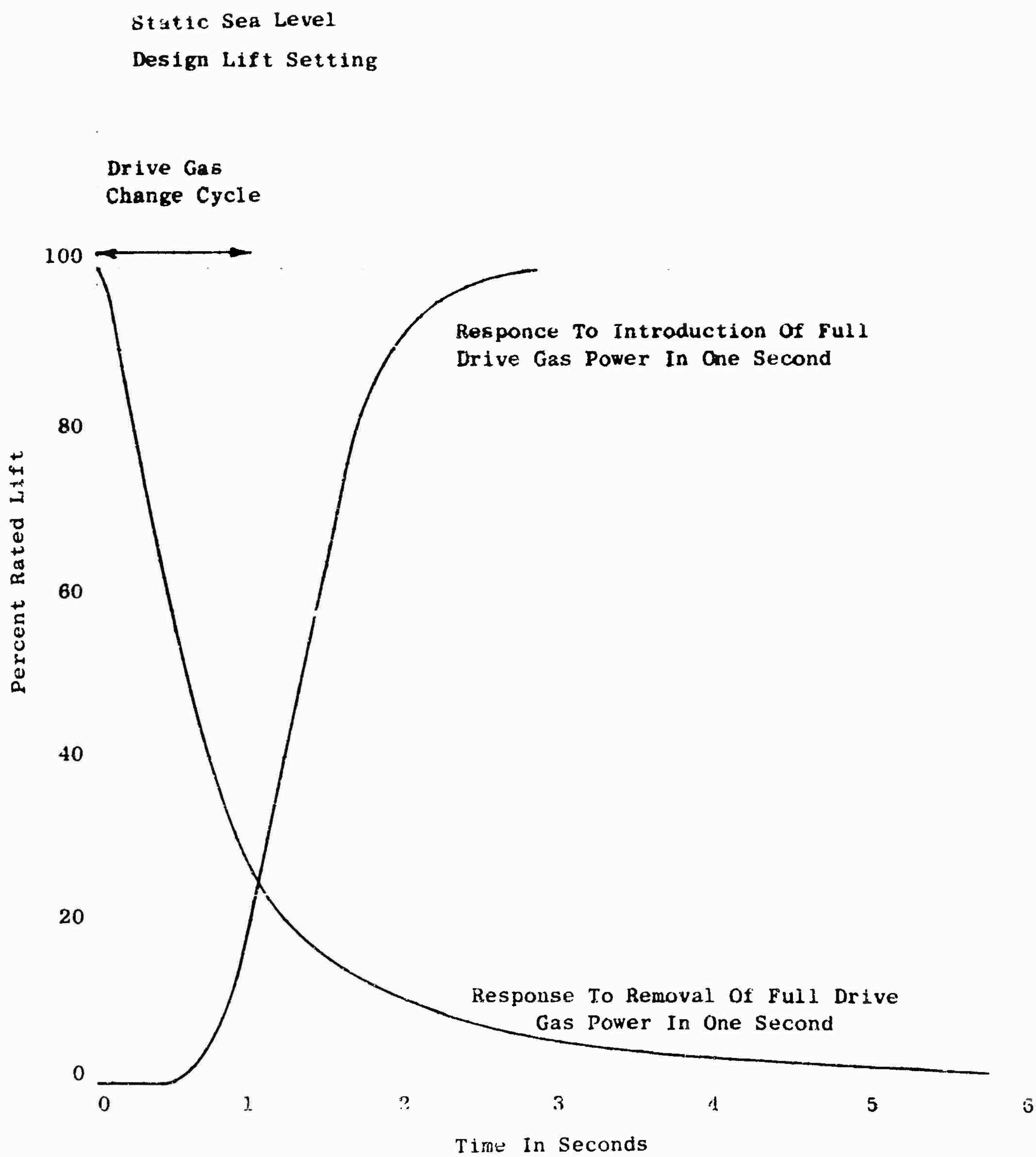


Figure 18. Estimated Transient Performance In Response To One Second Introduction Or Removal Of Drive Gas Supply

3.7 Drawings and Diagrams: The following General Electric Company drawings form a part of this specification:

X376 Installation	4012001-913
Layout, VZ-11 Inlet and Exit System for X376 Pitch Fan	4012028-545

3.8 Engine Design and Construction Changes: Changes to the design of this pitch fan which shall require change in this specification (including performance ratings, weight, envelope and limits) shall be submitted to U.S. Army TRECOM for approval. Changes not so affecting the specification shall be at General Electric's discretion during the research program, and shall not require approval of a Government Agency.

3.11.1.1 External Electrical Power: The only requirement for external electrical power shall be a 28 volt DC supply for pitch fan rpm sensor and overspeed control.

3.11.1.2 External Hydraulic Power: Not required.

3.12 Dry Weight of Complete Pitch Fan: The dry weight of the complete pitch fan as shown on installation drawing 4012001-913 shall not exceed 109 pounds. This weight includes four (4) pounds for fan rpm sensor and bearing temperature thermocouples. Mount hardware, other than that shown on the installation drawing, as well as inlet closure, fan inlet bellmouth and duct, guide vanes, gas ducting, fan exit duct and thrust reverser, if supplied, are considered aircraft components; their weights are not included.

3.12.1 Weights of Additional Equipment: An estimated total of 19.9 pounds of research instrumentation will be installed on the pitch fan during initial flight testing. The weight of the equipment is not included in the 109 pounds given in paragraph 3.12.

3.12.1.1 Weights of Additional Equipment Not Included: Items specifically not included in the weight and not considered a part of the pitch fan are:

- Inlet closure with actuator and control
- Inlet bellmouth and flow guide vanes
- Fan Inlet ducting
- Gas ducting up to scroll inlet including flange connection hardware
- Fan exit ducting
- Thrust reverser/exit closure

3.12.2 Weight of Residual Fluids: Not applicable.

3.14 Flight Maneuver Forces: The pitch fan and its supports shall withstand, without permanent deformation, the conditions specified in Figure 19 while in the turbojet mode (non rotating) and Figure 20 while in the lift mode.

3.16.1 Mass Moment of Inertia of Rotating Parts: The estimated mass moment of inertia of the pitch fan rotating parts, about the fan rotor axis is 1.293 slug-feet-squared.

Side Load	1.5 g
$\dot{\theta}$	0
$\dot{\Phi}$	0
$\dot{\Psi}$	0
$\ddot{\theta}$	6 r/s^2
$\ddot{\Phi}$	0
$\ddot{\Psi}$	0

Side Load	4.0 g
$\dot{\theta}$	2 r/s
$\dot{\Phi}$	0
$\dot{\Psi}$	0
$\sqrt{\dot{\theta}^2 + \dot{\Phi}^2}$	2 r/s
$\ddot{\theta}$	0
$\ddot{\Phi}$	6
$\ddot{\Psi}$	0

Side Load	2.0 g
$\dot{\theta}$	0
$\dot{\Phi}$	0
$\dot{\Psi}$	0
$\ddot{\theta}$	14 r/s^2
$\ddot{\Phi}$	0
$\ddot{\Psi}$	6.0 r/s^2

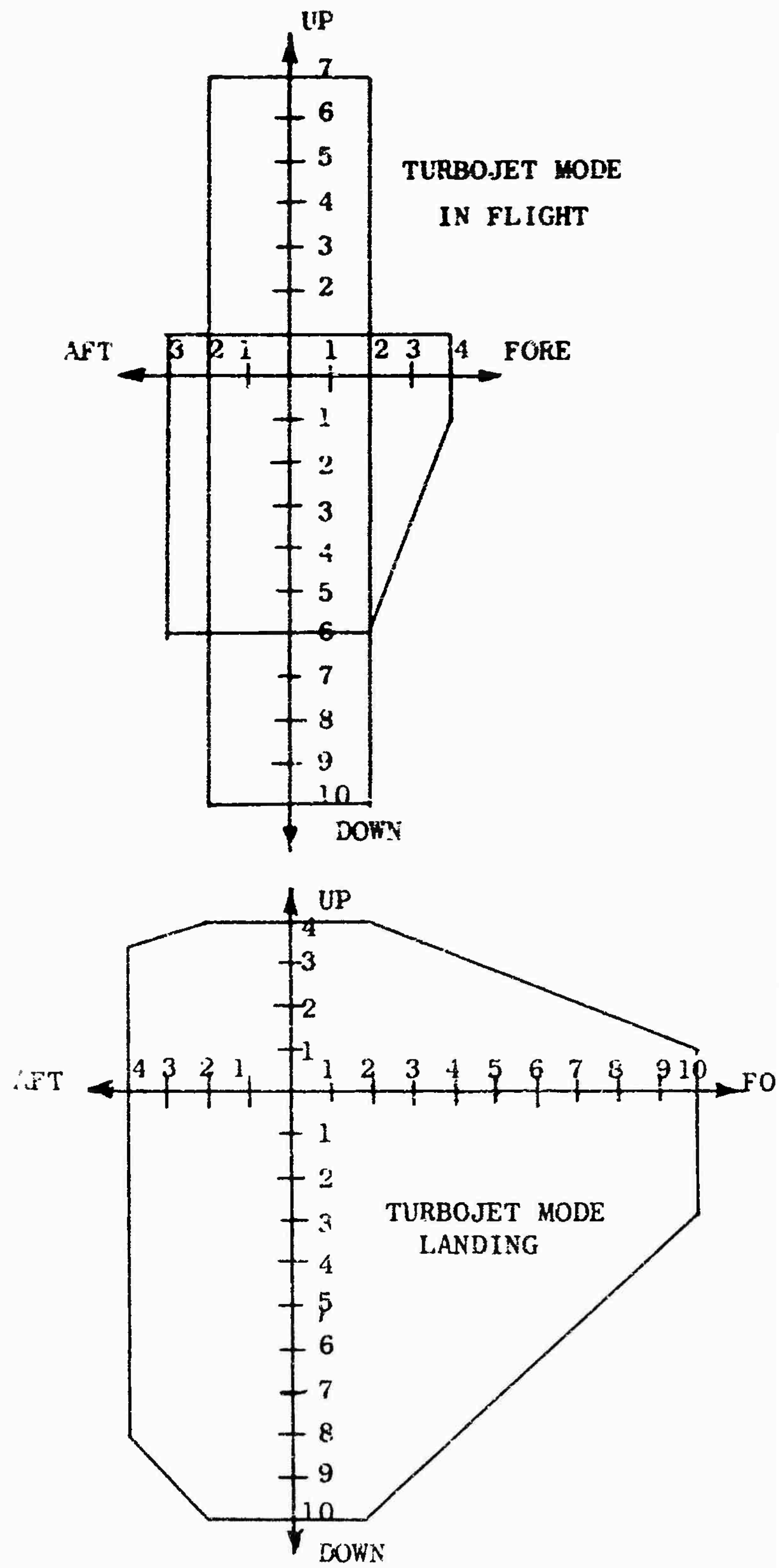
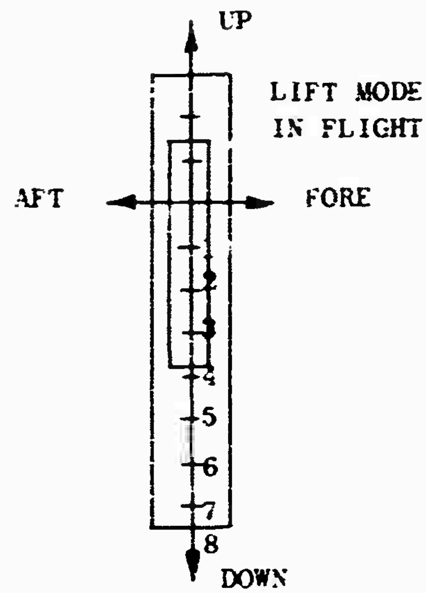


Figure 19. Maneuver Loads - Pitch Fan Off

Side Load	2.0 g
$\dot{\theta}$	0.8 r/s
$\dot{\Phi}$	0.8 r/s
$\dot{\Psi}$	0.5 r/s
$\sqrt{\dot{\theta}^2 + \dot{\Phi}^2}$	1.13 r/s
$\ddot{\theta}$	2.0 r/s^2
$\ddot{\Phi}$	2.0 r/s^2
Side Load	1.0 g
$\dot{\theta}$	0.8 r/s
$\dot{\Phi}$	0.8 r/s
$\dot{\Psi}$	3.5 r/s
$\sqrt{\dot{\theta}^2 + \dot{\Phi}^2}$	1.13 r/s
$\ddot{\theta}$	2.0 r/s^2
$\ddot{\Phi}$	2.0 r/s^2
Side Load	1.5 g
$\dot{\theta}$	0.8 r/s
$\dot{\Phi}$	0.8 r/s
$\dot{\Psi}$	0.5 r/s
$\sqrt{\dot{\theta}^2 + \dot{\Phi}^2}$	1.13 r/s
$\ddot{\theta}$	9.0 r/s^2
$\ddot{\Phi}$	16.0 r/s^2
$\ddot{\Psi}$	6.0 r/s^2



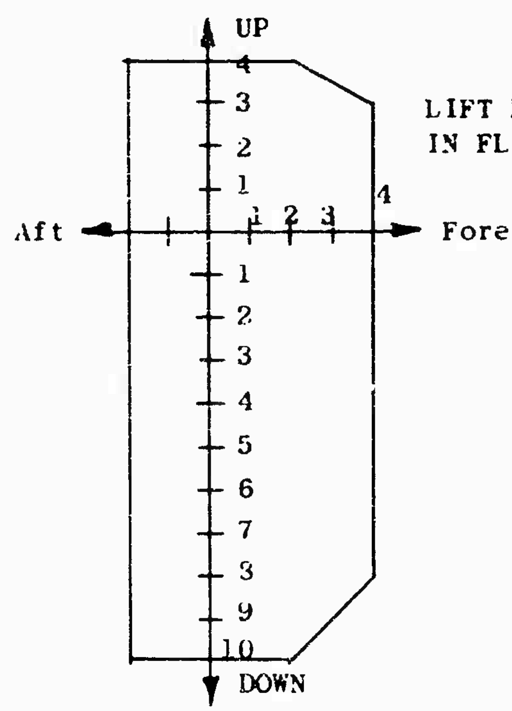


Figure 20. Maneuver Loads - Pitch Fan Operating

3.16.2 Moments of Inertia: The three-axis moments of inertia of the pitch fan are as shown below. These moments of inertia are estimated with respect to centers of gravity defined in paragraph 3.36.1. Orientation of components with respect to aircraft axes is shown on Installation Drawing 4012001-913.

Axis	Moment Of Inertia - Lb. Sec.^{2} Ft.
Pitch	2.530
Roll	2.646
Yaw	5.175

3.17 Pitch Fan Vibrations: The maximum permissible pitch fan vibration displacements shall be as follows:

Location	Maximum Displacement
Any location, any direction	15 mils maximum displacement or 8 g acceleration whichever is less.

3.18 Customer Air Bleed: Not applicable.

3.19.2 Pitch Fan Component Limiting Temperature: The pitch fan is designed for continuous operation when surrounded by air at an ambient temperature of 250°F.

3.19.3 Insulation Properties: The scroll, rear frame and front frame insulation blankets are 1/2 inch thick and have a conductivity of 0.8 BTU/ft^2/inch/degree Farenheit at a mean insulation temperature of 900°F.

3.20.1 Inlet Protection: Air inlet screens are not provided for the pitch fan and no provisions are made to incorporate them as an integral part of the pitch fan.

3.20.3 Turbojet Inlet Air Pressure and Temperature Variation: Not applicable.

3.20.3.1 Pitch Fan Inlet Air Pressure: For each individual installation it is necessary for the General Electric Company and the airframe manufacturer to jointly establish compatibility between the airframe and fan inlet to assure satisfactory operation.

3.20.4.2 Pitch Fan Inlet Connection Stresses: The X376 Pitch Fan inlet connection shall be of a slip joint type and the inlet ducting shall incorporate sufficient flexibility that airframe loads are not transmitted to the pitch fan.

3.21.1 Type of Anti-Icing: The pitch fan shall have no anti-icing provisions.

3.22 Fire Shield Attachment: Not applicable.

3.24.1.3 Allowable Pitch Fan Exhaust Connection Stresses: No provision is made for direct attachment of an exhaust duct to the X376 Pitch Fan.

3.25.1 Oil Supply: Not applicable.

3.26 Fuel System: Not applicable.

3.27 Pitch Fan Control System: During pitch fan operation the turbojet throttle quadrant, controlling turbojet rpm directly, provides open-loop control of pitch fan thrust level.

3.27.7.1 Potential Aircraft Control: The X376 pitch fan, through use with an appropriate modulated thrust reversing device, can be used to provide pitch control moments as well as basic pitch trim force in an airplane installation.

3.27.7.4 Lift Trim: Means are provided in the pitch fan for adjustment of scroll nozzle area in order to adjust basic pitch fan lift setting between nominal setting and high lift setting with one intermediate step. Nominal lift setting corresponds to 1628 pounds lift at standard sea level conditions. High lift setting corresponds to 1885 pounds lift at standard sea level conditions.

3.27.7.4.2 Fan Overspeed Control: Provision will be made for a pitch fan speed signal for possible use in any propulsion system overspeed protection system.

3.27.7.6.1 Reliability Analysis: A flight safety and system reliability analysis shall be jointly conducted by the General Electric Company and the airframe contractor and a report submitted to U. S. Army TRECOM.

3.29 Accessory Drives: Not applicable.

3.34 Identification of Product: Major parts shall be identified with part numbers and serial numbers. Additional nameplates shall not be required.

3.36 General Additional Information:

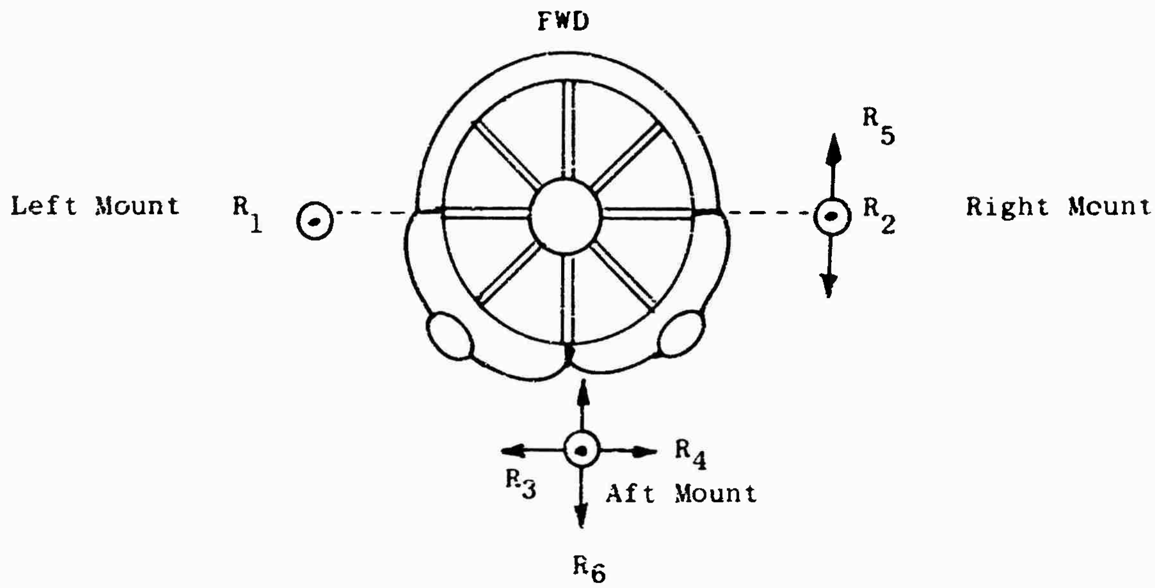
3.36.1 Center of Gravity: The center of gravity of the X376 Pitch Fan shall be in the centerplane of the pitch fan 1.75 inches above the rotor centerline and 2.27 inches aft of the rotor centerline.

3.36.3 Mount Loads: Reaction forces on pitch fan mounting points are defined in Table VI. Values are presented for unit load factors and maneuvers at steady state military power level, ARDC standard sea level atmosphere and do not imply operating limits. Limits are defined in paragraph 3.14.

TABLE VI

X376 Mount Reactions

Forces In Pounds Except As Noted



	R_1	R_2	R_3	R_4	R_5	R_6
Lift (% of Total Fan Lift)	-32.4% F_g	-32.4% F_g	-8.9% F_g			
1 g vertical	$\pm$ 46	$\pm$ 46	$\pm$ 13			
1 g axial	$\mp$ 17	$\mp$ 17	$\pm$ 33			$\mp$ 105
1 g side	$\mp$ 17	$\pm$ 17		$\pm$ 105	$\mp$ 92	$\pm$ 92
1 r/s pitch velocity	$\pm$ 165	$\mp$ 165				
1 r/s roll velocity	$\mp$ 165	$\mp$ 165	$\pm$ 330			

Note: 1) Forces are positive (+) in the directions shown and are forces acting on the fan.

2) Lift forces are those which are transmitted through fan mounts. Remaining 26.3 percent of fan lift occurs on fuselage and bell-mouth surfaces.

3) No scroll inlet "piston" forces. Pinned Bellows at inlets.

4) Gyro forces are computed at 4684 rpm.

3.36.4 Gas Duct Design Data: Basic system design and mount loads are based on zero shear, moment and axial piston loads at both pitch fan scroll inlet flanges. Therefore, duct connection loads which are different from this should be negotiated with the engine manufacturer.

Duct mechanical design should be based upon:

Maximum gas temperature = 1250°F average

Maximum gas pressure = 38 psia

3.36.6 Instrumentation: The X376 Pitch Fan will incorporate permanent instrumentation for flight safety and operating convenience consisting of a fan rpm pickup and fan bearing thermocouples.

3.36.7 Fan Contribution to Stability: The estimated aerodynamic force derivative for any translation of the fan along the X, Y or Z axis is $-2.374\sqrt{F_g \rho_o}$ lb/ft/sec where F_g is the pitch fan lift at that flight condition with no thrust reversal. The estimated aerodynamic moment derivative for any angular velocity of the fan about the pitch or roll axes is $-1.607\sqrt{F_g \rho_o}$ lb-ft/rad/sec and about the yaw axis is $-3.214\sqrt{F_g \rho_o}$ lb-ft/rad/sec. These moments and forces are taken about the center of the fan inlet bellmouth. These derivatives are all negative (i.e., they oppose the motion).

3.36.9 Bleed Gas Leakage: During turbojet mode operation a certain amount of leakage gas from the X353-5B diverter valve could be present in the pitch fan ducting. The amount actually flowing to the pitch fan would depend upon the installation. Any such leakage gas must be purged from the pitch fan cavity during turbojet mode operation to prevent fan cavity temperatures from exceeding 250°F.

3.36.19 Scroll Seal Leakage: During lift mode operation the pitch fan scroll seal estimated maximum leakage will be 0.2 percent.

4. QUALITY ASSURANCE PROVISIONS

4.1 The requirements for quality assurance shall be as specified in MIL-E-5007B 22 January 1959 as modified herein.

4.3 Qualification Tests: Not applicable.

4.4 Flightworthiness Test: Prior to aircraft flight, a Flightworthiness Test will be accomplished on an X376 Pitch Fan in accordance with Specification #115.

4.5 Acceptance Tests: Acceptance tests shall be conducted on each pitch fan in accordance with Specification #117.

5. PREPARATION FOR DELIVERY

5.1 Preparation for Shipment: Shipping containers shall be provided for the pitch fans and associated items to be transported which shall adequately protect the equipment en route. Containers for extended time storage shall not be required.

6. NOTES

6.2.1 Definitions: Except as noted below, the definitions and symbols used in this specification shall be as specified in MIL-E-5007B.

6.2.1.1 Qualification Tests: Not applicable.

6.2.1.2 Flightworthiness Tests shall be those tests conducted to demonstrate the suitability of the pitch fan for limited use in research aircraft flight testing.

6.2.2.1 Symbols:

Symbol	Quantity	Units
C_P	Specific heat at constant pressure	BTU/lb/°F
F_g	Gross thrust	pounds
F_r	Ram Drag	pounds
g	Acceleration of Gravity	ft/second^2
$HP_{15.3}$	Ideal Horsepower at Scroll Inlet	horsepower
$\%N_f$	Fan Speed	percent rpm
$\%N_g$	Turbojet Speed	percent rpm
P	Pressure	psia

6.2.2.1 Symbols: (cont'd)

Symbol	Quantity	Units
P_{am}	Ambient Pressure	psia
r/s	Angular Velocity	radius/second
T	Temperature	^{o}R
T_{am}	Ambient Temperature	^{o}F
T_{S}	ARDC Standard Ambient Temperature	^{o}F
V_{P}	Flight Speed	knots
W	Weight flow	pounds/second
Δ	Correction factors	
K	Correction factors	
C	Correction factors	
γ	Ratio of Specific Heats	
δ_{o}	Pambient (PSIA)/14.696	
θ_{o}	Tambient (^{o}R)/518.7	
ρo	Ambient Density	lbm/ft^{3}
$\bar{\omega}$	Percent Velocity Head Loss	percent
$\dot{\theta}$	Pitch Velocity	radius/second
$\dot{\Phi}$	Roll Velocity	radius/second
$\dot{\Psi}$	Yaw Velocity	radius/second
$\ddot{\theta}$	Pitch Acceleration	$radius/second^{2}$
$\ddot{\Phi}$	Roll Acceleration	$radius/second^{2}$
$\ddot{\Psi}$	Yaw Acceleration	$radius/second^{2}$

Numerical subscripts after ΔP, P, T, W, and ω identify stations as shown in Figure 21.

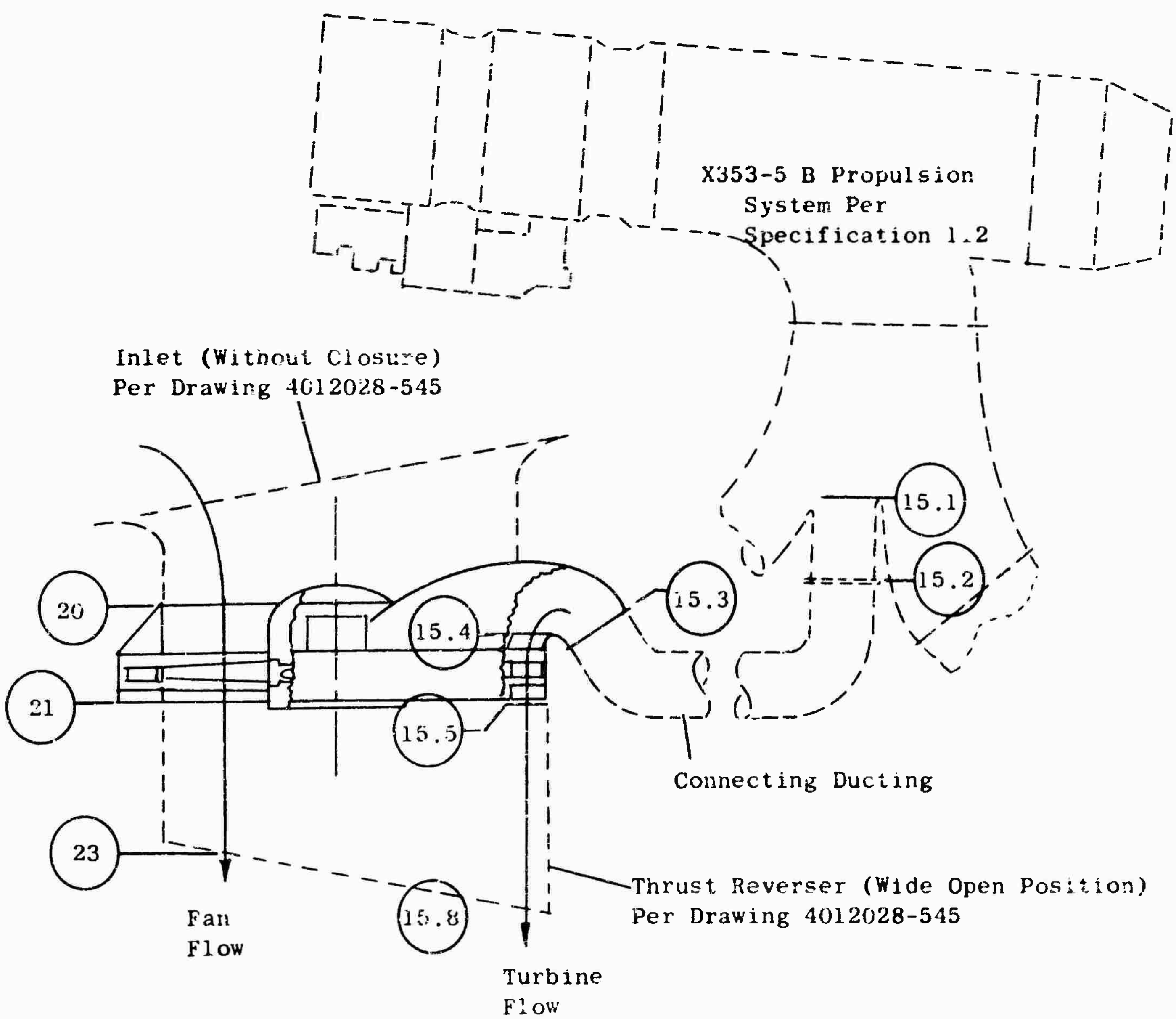


Figure 21. Station Designations